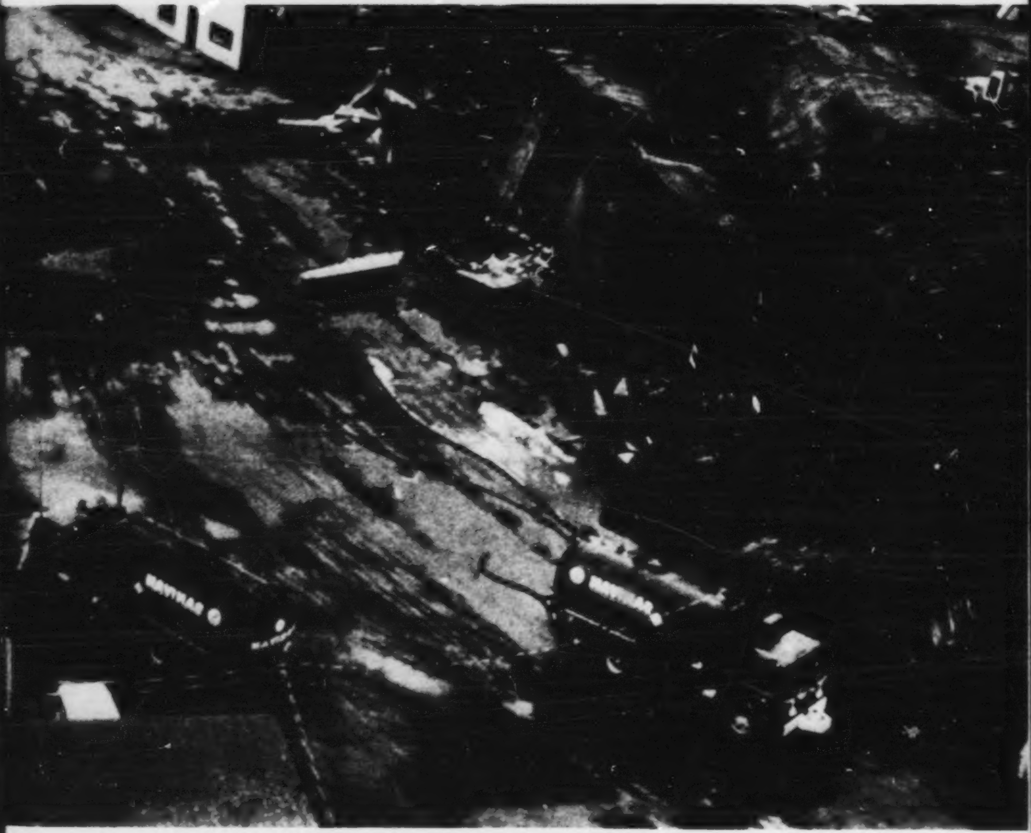
PROCEEDINGS OF THE SEVENTH TECHNICAL SEMINAR ON CHEMICAL SPILLS

COMPTE RENDU: 7^e COLLOQUE TECHNIQUE SUR LES DÉVERSEMENTS DE PRODUITS CHIMIQUES



JUNE 4-5, 1990
EDMONTON, ALBERTA

4 ET 5 JUIN 1990
EDMONTON (ALBERTA)

Environment Canada Environnement Canada

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PROCEEDINGS

Seventh Technical Seminar on Chemical Spills

June 4-5, 1990
Chateau Lacombe
Edmonton, Alberta

Seminar sponsored by

Technology Development Branch
Environmental Protection
Conservation and Protection
Environment Canada

COMPTES RENDUS

Septième colloque technique sur les déversements de produits chimiques

4 au 5 juin, 1990
Chateau Lacombe
Edmonton (Alberta)

Colloque commandité par

Direction du développement technologique
Protection de l'environnement
Conservation et Protection
Environnement Canada

90-05341/

© Minister of Supply and Services Canada 1990
Catalogue No. En 40-327/1990
ISBN 0-662-57534-2
BEAUREGARD PRINTERS LIMITED

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No de catalogue En 40-327/1990
ISBN 0-662-57534-2
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Photographie de la couverture - photographie aérienne de l'entrepôt de BPC de Saint-Basile-le-Grand juste après l'incendie.

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A THREE-DIMENSIONAL OIL AND CHEMICAL SPILL MODEL AND COUPLED GEOGRAPHICAL INFORMATION SYSTEM

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ABSTRACT

The present status of a model for natural resource damage assessments is discussed. The model can address a wide range of spatial and temporal scales. The transport equations for both pollutant and biota are solved with a three-dimensional Lagrangian particle methodology. The model can simulate continuous releases of a contaminant, with representation of complex coastal boundaries, variable bathymetry, multiple shoreline types, and spatially variable ecosystem habitats. A graphic interface gives the user complete and facile control of the dynamic transport and biological submodels, as well as the ability to display elements of the underlying geographical information system (GIS) data base. The model is being implemented on a 386 PC.

1. INTRODUCTION

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) was enacted in the United States in response to proliferating environmental problems associated with accidental releases of chemicals, oil, and refined petroleum products. CERCLA specifically allows the Federal or a state government, as trustee of affected natural resources, to claim compensation for damages to those resources, as well as the reasonable cost of conducting a natural resource damage assessment. Such assessments may be conducted using either a Type A (simple) or Type B (complex) methodology, the simpler methodology being indicated when a refined, site-specific Type B assessment is not warranted in a cost/benefit sense.

The final Type B regulations were published on August 1, 1986 (51 FR 27674). The first Type A methodology (Reed et al., 1989) was developed for the coastal and marine environments (CME), and was published in the Federal Register on March 20, 1987 (52 FR 9042). The methodology described herein is applicable to the Great Lakes environments (GLE), including connecting channels.

Like the CME model, the GLE model is comprised of a series of linked submodels and data bases (Figure 1). The GLE model is supported by a geographical information system (GLS) which supplies spatially gridded environmental and biotic information to the dynamic physical fates and biological submodels. The user is required to supply the following information to the model:

(1) identification number of spilled substance,
(2) amount spilled,
(3) duration of release,
(4) time and date of release start,
(5) a wind time series,
(6) latitude and longitude of release point,
(7) to what extent cleanup of the spill was carried out.

The GIS supplies the data necessary to define the simulated environment within which the spill occurs:

(1) bathymetry
(2) shoreline types
(3) ecological habitat
(4) ice cover
(5) river currents
(6) climatological lake currents
(7) sediment type
(8) water temperature
(9) thermocline depth.

These parameters vary spatially within the model. Ice cover, currents, water temperature, and thermocline depth also vary temporally, and are updated periodically by the GIS.

The wind time series is supplied as an external file by the user. New wind speeds and directions are required for every 3 to 12 hours, beginning 24 hours before the start of the release, and continuing for the duration of the release, or until no surface slick remains. Upon reaching the end of this file, the model uses climatological values from the GIS data base.

The physical fates model then computes the dynamic distribution of the spilled substance in the lake or channel environment. Computations continue until either (a) all environmental exposure levels are below a minimum threshold, or (b) a surface slick or water column concentration above the threshold is advected outside the model domain. Under case (a) above, control is passed to the biological effects model and computations proceed. If one of the conditions under (b) occurs, the model will restart using a larger grid size or an adjacent downstream grid, so that damages may be computed for the active life of the release.

The biological effects model computes (1) direct lethal effects on larvae, juveniles and adult fish, waterfowl, shorebirds, and lower trophic biota; (2) indirect and long term effects involving the eventual loss of fish as a result of lost larvae and juveniles, and birds as a result of lost broods; (3) indirect effects of lost lower trophic biota and non-commercial species through the food web. These effects are computed by dynamic juxtaposition of biotic distributions with the distributions of the spilled substance on the water surface, in the water column, in the sediments, and along the shoreline.

The economic submodel then proceeds to compute damages based on methodologies still to be devised. All damages are then summed to produce a final damage measure in U.S. dollars for the release.

2. PHYSICAL FATES SUBMODEL

The purpose of the physical fates submodel is to estimate the distribution of a contaminant on the water surface, concentrations in the water column, and in the sediments (Figure 2). The GIS establishes an initial boundary and grid system for a specific application of the NRDAM/GLE. The GIS then supplies parameter values for depth, sediment type, ecological habitat, shoreline type, and ice cover throughout the established domain. The chemical data base supplies chemical parameters required by the submodel. The user is required to supply a wind time series specific to the time and location of the spill. The GIS supplies climatological values for air and water temperatures; these may be overridden by the user.

If the specific gravity of a spilled chemical is less than or equal to that of water, the model employs surface spreading, advection, entrainment, and volatilization algorithms to determine transport and fate at the surface. A contaminant with specific gravity greater than water is modeled by a convective jet algorithm which allows the contaminant plume to reach an equilibrium position in a stratified water column, or to sink to the bottom. In general, some fraction of any contaminant spilled will exist in both the water column and the sediments. In the water column, horizontal and vertical advection and dispersion are simulated by random walk procedures. Partitioning between the particulate adsorbed and dissolved states is calculated based on linear equilibrium theory. The contaminant fraction that is adsorbed to suspended particulate matter is assumed to settle at a rate typical for the lacustrine environment. Contaminants at the bottom are mixed into the underlying sediments according to a simple bioturbation equation.

The model is designed to simulate fates of pure hazardous substances, crude oils, and petroleum products. Crude oil and petroleum products are actually complex mixtures of hydrocarbons. For modeling purposes, crude oils and petroleum products are represented by four components:

1. aromatics with molecular weight less than 100 grams/mole; represented by a 50/50 mixture of benzene and toluene;

2. aromatics with molecular weight between 100 and 160 grams/mole;

3. a relatively insoluble volatile portion which constitutes the remainder of the total volatiles in the parent substance; and

4. a residual fraction which is neither soluble nor volatile.

The process pathways for these components are shown in Figure 3. Toxicity in the water column is associated only with the aromatic fractions.

The physical environment is divided into six general compartments: the atmosphere, the sea surface, the upper and lower water column (as defined by the presence of a thermocline), the lake bottom, and the shoreline. The model distributes a contaminant dynamically within and among these compartments. Only the atmospheric compartment has no physical representation and no linkage to the biological effects submodel.

The model solves the generalized transport equations,

$$\frac{\partial C}{\partial t} + \vec{V} \cdot \vec{\nabla} C = \vec{\nabla} \cdot D \vec{\nabla} C - \sum_{j=1}^{n} r_j C \ . \qquad (1)$$

On the water surface and the shoreline, "concentration" C has units of mass per unit area, whereas in the water column the units are as usual mass per unit volume. The terms r_j in Equation (1) are process rates, including

- evaporation from surface slicks,
- spreading of surface slicks,
- deposition from water surface onto coastline,
- entrainment and dissolution into the water column,
- volatilization from water column,
- degradation (surface, water column, shoreline, sediments),
- mass removal by cleanup,
- addition of mass from continuous release,
- dissolution from sediments to water column,
- deposition from water column to sediments.
- removal from coastline to water column.

These process rates results in mass transfers from one model compartment to another.

An Eulerian (fixed) grid system is established by the NRDAM/GLE software for each application of the model. The array sizes in the model are fixed (i.e. there is a constant number of grid cells in each of the x (East) and y (North) directions. The physical dimensions of the overall grid are variable from one application to another. The grid must be large enough so that all damages associates with a given release occur inside the grid, otherwise some portion of the damages will not be computed. On the other hand, the individual grid cells should be as small as possible (limited by resolution of the environmental data), so that peak contaminant levels in the sediments and environmental variability are properly resolved.

For a substance which floats the grid system in a lake is established such that the surface slick will remain inside until it beaches or is dissipated. (The exception is that contaminant mass may be transported outside the grid if it is thereby transported into an adjoining lake or connecting channel.) The model performs a series of preliminary transport calculations using the input wind time series, the duration of the release, and the entire lake within which the release occurs. By releasing particles at discrete times during the release interval and tracking them forward in time as they are transported by the wind, initial boundaries are estimated for the study area.

For a pollutant that sinks in the water column but is intercepted at the thermocline before reaching the lake bottom, the same domain-size estimation procedure is followed as for surface slicks, but the effect of the wind is weaker. Maximum transport time is based on an estimate of the time for peak concentrations in the plume to fall below the acute threshold value for the substance.

For spills which occur in connecting channels, a fixed grid system is used for all applications. The grid system has been selected based on the need to resolve the geometry of the rivers, the availability of natural resource information along the rivers, and best available estimates of transport velocities. Thus each river is represented by a series (or "cascade") of interlocking grids, through which a spilled substance is transported. The grid systems have been selected based on the need to resolve the geometry of the rivers, and the availability of natural resource information along the rivers. Grid systems in connecting channels are pre-set with grid cells ranging from 150 to 1000 m on a side.

The use of Lagrangian particles in the contaminant transport calculations simplifies the problems associated with mass transfer from one grid to the next. The governing characteristics of a particle (mass, latitude, longitude, depth, and time since release) are written to a temporary file when a particle exits a grid into another grid. When all damages have ceased in the first grid, then the simulation continues in the subsequent grid, with mass particles being entered into the new grid at the appropriate locations and times, read from the temporary file.

A second expanding, translating ("floating" or Lagrangian) 3-dimensional grid system is used to resolve concentration levels in the water column. At each timestep for which water column concentrations are to be output to the biological submodel, the Lagrangian grid is "stretched" in the vertical and horizontal dimensions until all contaminant particles are within the grid boundaries, at which time concentrations are computed within each three dimensional grid cell. This expanding grid allows the model to adjust to a wide range of spill sizes, and reduces the interdependence between the dimensions of the Eulerian (fixed) transport grid and the size of the spill.

The physical fates submodel uses a variable timestep to resolve transient toxic effects in the water column, and to compute efficiently long-term concentration changes in the sediments. The model computes a reference timestep, Δt, based on the Eulerian (fixed) grid size and the maximum water column transport velocity U_{max}:

$$\Delta t = (\Delta x \Delta y)^{1/2}/2\ U_{max}$$

where Δx and Δy are the grid cell dimensions in the x and y directions. In shallow water, the timestep may be limited by the vertical mixing velocity, in which case the reference timestep becomes

$$\Delta t = 0.25\ d^2/6\ D_z.$$

The initial timestep is then set equal to a fraction of the reference value, and allowed to increase with time to the reference value. A small initial value is necessary to allow resolution of evaporation processes in the case of a floating substance, and to resolve the formation of a momentum/density jet in the case of a substance which sinks.

Thereafter, the timestep is equal to the reference value, until all water column concentrations are below a specified threshold value, and all contaminants in the water column have been advected outside the fixed grid boundaries or settled to the bottom sediments. Then the model advances on daily, monthly and seasonal timesteps until all sediment and shoreline concentrations are also below threshold levels.

The maximum number of particles which can be represented in the model is fixed. If the total number at a given time is near the maximum, and additional particles are needed to allow continuous input of contaminant, the model performs a compression of the particle arrays. This compression is based on the identification of geometrically "nearest-neighbors", and the combining of their attributes: mass, time-since-release, x-, y-, and z-locations. A new particle is created with mass equal to the sum of the masses of the two nearest-neighbor particles, and location and time-since-release are computed based on linear-weighting of the existing values based on the mass of each particle. This process is continued until sufficient "free space" is created in the arrays to allow the program to proceed.

The number of particles in the model could sometimes be so small that discontinuities appear in the concentration field. To avoid this problem, a splitting procedure is used to create multiple particles within the concentration field of a single particle. The mass of the original particle is then shared among the new multiples, with new physical locations chosen at random within one standard deviation of the center of the original concentration field.

3. GEOGRAPHIC INFORMATION SYSTEM AND DATA BASE

A geographical information system (GIS) and data base are built into the NRDAM/GLE. Once the model grid system has been selected, the GIS fills model arrays with necessary variables and parameters. Table 1 lists the quantities supplied, and the sources of the underlying information. Depending on whether the model grid cells are larger or smaller than the resolution of the source data, averaging or interpolation is performed to fill each cell in in each model array.

Transport currents in the model are of two types: wind-driven currents in the lakes, and pressure gradient currents in the connecting channels. Time-dependent wind-driven lake currents are simulated using a rigid lid, two dimensional barotropic model developed specifically for the Great Lakes (Schwab et al., 1981). The hydrodynamic model uses the wind time series supplied by the user to create a complete time series of currents for the lake(s) in which the spill occurs. Initial conditions for the wind-driven hydrodynamic model are given by the stream function values corresponding to mean river inflow and out flow velocities (e.g. Schwab et al., 1989). The GIS then interpolates these currents onto the grid system being used by the physical fates submodel, the grid system being used by the physical fates submodel.

Table 1. Quantities contained in the geographical data base.

Quantity	Dimensions	Resolution	Source
Habitat	***	0.1-10 km	****
Bathymetry	m	0.1-2 km	GLERL
Ice Cover	% coverage	1-5 km	GLERL
Sediment Type	*	1-10 km	CCIW
Shoreline Type	**	0.1 -1 km	COE, NOAA
Currents	m/sec	0.1-10 km	GLERL, CU
Climatological			
- Winds	m/sec	variable	EC
- Temperatures	°C	variable	EPA, EC
- Thermocline Depths	m	variable	EPA

* % sand, silt, clay (Thomas, 1980)
** sea wall, gravel, sand, mud, marsh
*** see sections 3 and 6

GLERL	Great Lakes Environmental Research Laboratory
CCIW	Canadian Center for Inland Waters
COE	Army Corps of Engineers
NOAA	National Oceanic and Atmospheric Administration
CU	Clarkson University
EPA	Environmental Protection Agency
EC	Environment Canada

Currents in the connecting channels are computed for mean flow conditions, based on streamtube analysis (Yapa and Shen, 1986; Shen et al., 1986; Shen and Yapa, 1988).

The user is required to supply a wind time series (data set) for each application of the model. This data set can be created interactively from within the NRDAM/GLE, by directly editing an ASCII file external to the system, or by automated processing of a source file (e.g. airport or weather station time series) into the format required by the model. These operations are explained in detail in the User's Manual, Volume II. The GIS data base also contains climatological winds (Saulesleja, 1986), which are used when the user-supplied wind data set ends.

Bathymetric (depth) data were digitized by GLERL personnel, and interpolated onto fixed grid systems for use in a variety of models (Schwab and Sellers, 1980). The gridded data is used as the basis for computations by the NRDAM/GLE.

Sediment type data has been supplied by Dr. Richard Thomas of CCIW. This data gives percentage composition in the top 3 cm of bottom sediments for sand, silt, and clay.

The ice data is the gridded mean or "normal winter" data used in the NOAA Ice Atlas (Assel et al., 1983). This data gives the ice concentrations for 5 x 5 km grid cells as a percentage ranging from 0%-100% in 10% increments. The grid cell locations were converted to longitude and latitude for use in NRDAM/GLE.

3. BIOLOGICAL EFFECTS SUBMODEL

The biological effects submodel estimates short-term losses (injury) resulting from a spill (i.e., losses at the time of the spill and while toxic concentrations remain in the environment) in terms of direct mortality and biomass not produced because of the loss of food resources. Losses are estimated by species or species group for fish and wildlife (birds and mammals).

The environment is represented by a grid of habitats with each grid coded as to habitat type. The habitat grid matches the fixed (Eulerian) physical grid set up by the physical fates model using the GIS data base. A grouping of habitat grids with the same habitat code constitutes an ecosystem in the biological submodel. Fish, birds, mammals and rates of lower trophic level productivity are assumed constant and evenly distributed across an ecosystem within each of four seasons. Fish, birds and mammals are assumed to move at random within each ecosystem during a single season. Fish eggs and larvae are assumed constant and evenly distributed across each ecosystem within each month of an annual cycle. Planktonic stages are advected with the currents.

Habitats include deepwater, nearshore, and wetland environments in the Great Lakes region. Habitat types are defined by depth, proximity to shoreline(s), bottom type, dominant vegetation type, and the degree to which pollution stress presently exists. The water column may be a single layer or divided into two layers by a thermocline.

The physical fates submodel calculates concentration in three-dimensional space and in time. This information is passed to the biological effects submodel where the portion of exposed organisms in each habitat type which would be killed is calculated from dissolved concentration (in the water or sediment). Mortality is calculated using laboratory acute toxicity test data (LC50, concentration lethal to 50% of test individuals) corrected for temperature and time of exposure, and assuming a log-normal relationship between percent mortality and dissolved concentration. Organisms killed are integrated over space and time and by habitat type to calculate a total short-term kill. This total short-term kill occurs from the time of the spill until the time the contaminant is dispersed to the point where concentrations are below toxic levels.

Biomass which is not produced as a result of a loss of food resources is estimated using a simple food web model. Lost primary (plant) and secondary (herbivore) production in each habitat is estimated using the EC50, the concentration where growth rate is 50% of the clean control, correcting it for temperature and assuming a log-normal relationship between percent of uninhibited growth rate and concentration. Primary and secondary production losses are integrated over space and time and by habitat to calculate the total weight not produced during the spill. The rates of production are assumed to return to normal immediately following the dispersion of the spill to non-toxic concentrations. The portion of the lost primary production which would have produced primary consumer (secondary producer or herbivore) biomass is estimated based on observations ecological efficiency made on representative ecosystems. The fractions of the lost secondary production which would have been consumed by each of their predators (fish, birds and mammals) are assumed to be proportional to the biomass of that predator relative to the sum of its competitors. The output of this part of the submodel is lost production of the various fish, bird and mammal species or species categories as a result of the spill. This is added to the total direct kill to yield a total loss of biomass by habitat as a short-term result of the spill.

Potential long-term losses (losses seen after the spill has dissipated) which can result from a spill of a toxic substance include: (1) lost recruitment to a fishery of the larvae and juveniles killed at the time of the spill; (2) lost future growth of the adults killed at the time of the spill; (3) changes in food web structure and, therefore, productivity of specific trophic levels and populations; and (4) chronic effects of sublethal levels of contaminants in tissues or the environment, such as reduced growth rate or loss of reproductive potential. The latter two effects are considered beyond the scope of this model, both due to the complexity of developing such models, which necessitates that they be site-specific, and to the lack of quantitative information required to run these models (e.g. see Hansen, 1984). Thus, the impacts estimated in the biological submodel are the results of acute toxicity and resulting direct effects on long-term productivity and yield: lost recruitment and lost growth. It is assumed that the spill has no indirect (chronic) effects or feedbacks after the spill has dissipated, such as changes in mortality due to density-dependent effects, changes in food web structure and predator-prey relationships, or changes in reproductive potential. The spill impact extends only for the life span of the species considered, and growth, biomass and reproduction are assumed to return to normal immediately after the effects of the spill have dissipated.

For fish, it is assumed that a constant mortality rate (due to natural causes) applies to juveniles and adults of a species, juveniles and adults inhabit the same habitat at the same time, there is a constant fishing mortality rate on adults, there is a constant larval survival rate, and the growth rate for adults past the age of recruitment to the fishery follows the von Bertalanffy relationship (Ricker, 1975). Using these assumptions and standard steady-state fisheries models, the age structure of a population and long-term losses in yield as the result of the spill may be estimated (Ricker, 1975). The initial kill in numbers by age is calculated from fish biomass killed, weight as a function of age, and natural and fishing mortality rates. For each year following the spill, the lost catch, calculated from fishing mortality, weight by age and average number alive during that year, is passed to the economic damages submodel. Thus, only those individuals which would have been caught in present and future years, and not those which would have died naturally, are included in the quantification of the effects of the incident.

The relatively high mortality rates of fish larvae are included in the biological effects submodel, since a high number of the larvae killed at the time of the spill would have died regardless of the spill. Larvae and older age classes are not assumed to be inhabiting the same environment concurrently, and their losses are calculated separately.

For waterfowl and mammals, losses to hunting are calculated assuming constant natural and hunting mortality rates over time after the spill. For all wildlife, losses to viewing are calculated as the number not left alive in present and future years as the result of the spill, after constant natural mortality (and hunting mortality) is subtracted.

Lost catch (or lost number hunted) as the result of area closures to fishing or hunting is also calculated in the biological effects submodel for each species or species group. Catch lost due to closure, but not due to mortality, is added to mortality-induced catch losses to calculate total lost catch. Total lost catch by season, year and habitat type is output to the economic damages submodel where monetary damages are calculated.

The biological effects submodel was designed to be generally applicable, while restricting the data and parameter requirements to information which is readily available. Thus, biological data were compiled for a series of habitat types within each of the lakes in the Great Lakes region, as opposed to specific information for each possible geographic location.

Data contained in the biological data base are seasonal estimates of fish biomass per area (grams wet weight per square meter), numbers of birds and mammals per area, and rates of production for lower trophic levels (plants and invertebrates).

Parameters required for the biological submodel include estimates of natural and fishing (hunting) mortality rates, available from the fisheries and wildlife literature; age-specific growth rates, available from length- or weight-at-age catch data; and age at recruitment and life span. The spawning areas and times for fish species, and development information for the young of all species groups are also required. All of these parameters are included in the data base as specific to habitat within each geographic region.

4. ECONOMIC SUBMODEL

The economic damages submodel calculates damage to both commercial and recreational fisheries. The quantity of fish which would have been harvested in the absence of the incident is an output of the biological effects submodel. The value of the reduction in harvest or other use minus the cost of harvesting or using the resources is the lost in-situ use value of the resource. This provides a measure of the damages resulting from the spill.

Damages resulting from injury to lower trophic-level, non-commercial organisms are based on the ultimate loss in the in-situ use value of predator species (commercial and recreational fisheries, waterfowl and shorebirds, and mammals) which occurs when an incident affects the productivity of the food web. The food web model developed in the biological effects submodel quantifies the biological injuries which arise over time as a result of the incident. Economic damages are measured using the concepts and data applicable to commercial and recreational fisheries, to waterfowl and shorebirds, and to mammals.

Injury to waterfowl and shorebirds results in losses of consumptive (hunting) and non-consumptive (e.g., viewing, photographing) in-situ use values. The quantification of biological injury to waterfowl and shorebirds is an output of the biological effects submodel. Damages resulting from losses in consumptive use are measured using available estimates of the marginal value of an additional waterfowl (duck or goose) harvest. Damages arising from losses in non-consumptive use value for non-game species are measured by employing an estimate of the marginal change in visitor days associated with a change in bird population for a wildlife refuge. Lost visitor days are evaluated in terms of monetary damages based on published unit day values.

Damages caused by injury to public beaches are estimated by the lost in-situ use value of a length of beach which depends on the season, the type of public beach affected and the extent and duration of the injury.

Restoration, mitigation, and existence values are also being considered for inclusion in the model. However, the associated methodologies have not yet been fully defined.

5. CONCLUSION

This paper discusses the present status of an on-going project to develop a numerical model for natural resource damage assessment in the Great Lakes. Although the model is well-defined and operational in broad terms, some details are expected to change in the near future. The final model system will operate on a personal computer with a mouse-driven graphical user interface. The final version is expected to be available within the next year.

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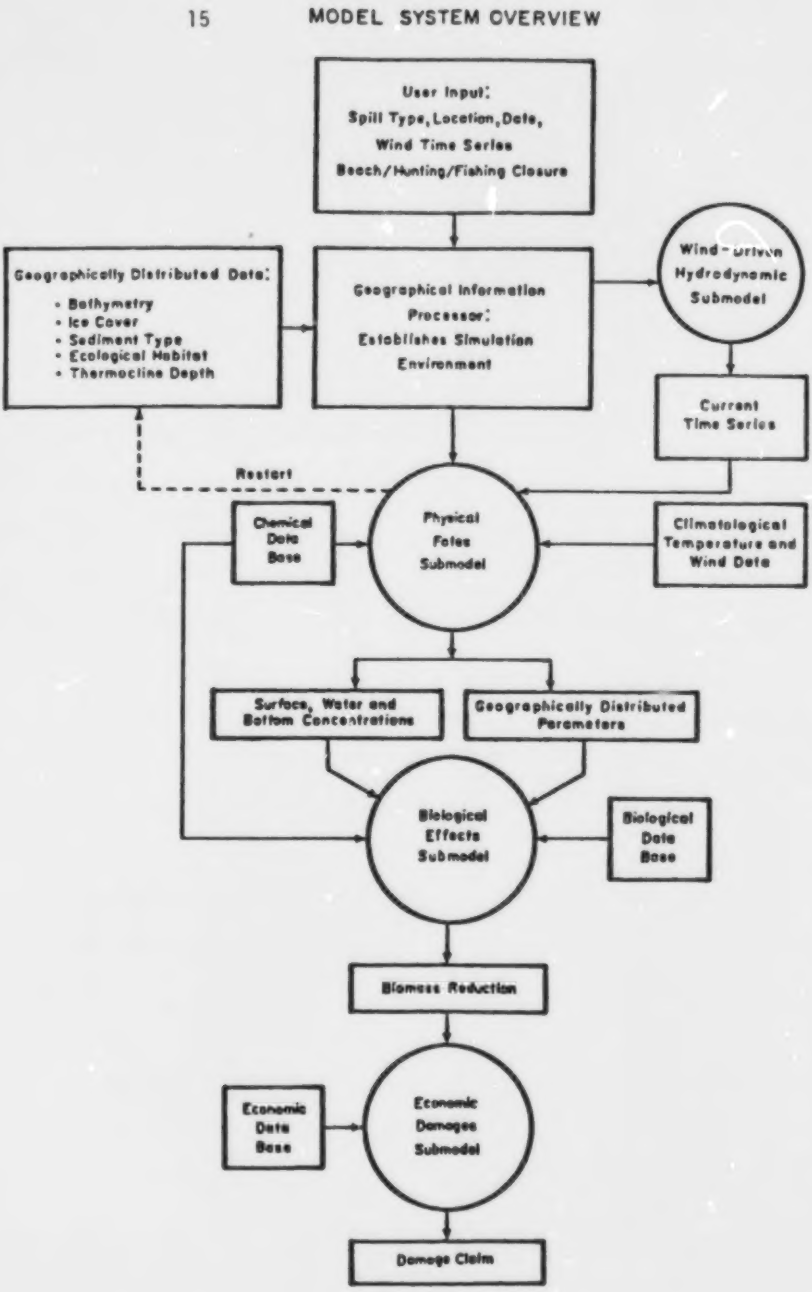
15
MODEL SYSTEM OVERVIEW
User Input:
Spill Type, Location, Date,
Wind Time Series
Beach/Hunting/Fishing Closure
Geographically Distributed Data:
• Bathymetry
• Ice Cover
• Sediment Type
• Ecological Habitat
• Thermocline Depth
Geographical Information Processor:
Establishes Simulation Environment
Wind-driven Hydrodynamic Submodel
Current Time Series
Restart
Chemical Data Base
Physical Fates Submodel
Climatological Temperature and Wind Data
Surface, Water and Bottom Concentrations
Geographically Distributed Parameters
Biological Effects Submodel
Biological Data Base
Biomass Reduction
Economic Data Base
Economic Damages Submodel
Damage Claim

Figure 1 Overview of the Natural Resource Damage Assessment Model for Great Lakes Environments (NRDAM/GLE).

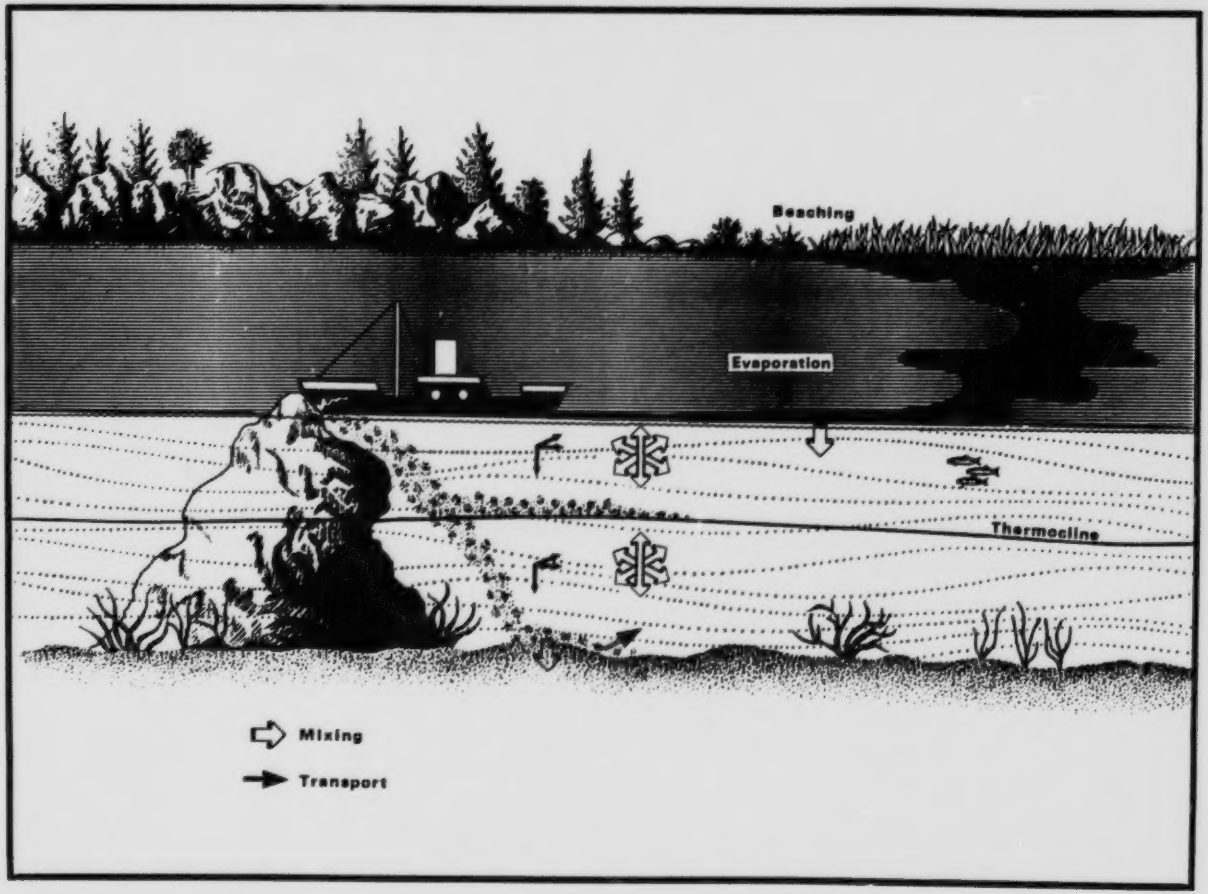
Beaching
Evaporation
Thermocline
Mixing
Transport

Figure 2 Graphical schematic of processes in the physical fates submodel.

Consequence Analysis of Atmospherically Dispersed Toxic Chemical Releases: Modeling for Planning and Emergency Response

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New Jersey Department of Environmental Protection
CN 027, Trenton, New Jersey 08625

Introduction

Recent state and federal regulations in the United States require that consequence analysis based on dispersion analysis be conducted in the planning stage to avert potential catastrophes from accidental releases of toxic gases or vapors. Among state-of-the-art methods in accidental release dispersion analysis, no consensus exists as to which modeling equations and assumptions are most accurate, except for the case of neutral-buoyancy Gaussian dispersion. Neutral-buoyancy dispersion modeling is widely used for predicting concentrations from highly-diluted controlled stack releases. However, for accidental releases at high concentrations, the most common case is negative buoyancy or heavier-than-air behavior. It is unlikely that any existing model describing this behavior will be accepted by scientific consensus until all definitive validation is completed. This validation, including the need for numerous experimental programs, is probably a decade away. Meanwhile, careful selection of available models is necessary since predictions among some models may vary by more than an order of magnitude.

This paper describes the results of an extensive study of existing publications and available models, and attempts to consolidate those equations and assumptions which appear to yield the most accurate predictions. The work has led to the continuing development of a negative/neutral buoyancy model ACTOR (Analysis of Consequences of Toxic Releases). The intention of the ACTOR model is to provide high accuracy based on presently available data, flexibility for future modification and integration of the distribution of concentration predictions for more meaningful consequence analysis.

Use in Consequence Analysis

The primary feature of the ACTOR model, which distinguishes it from most other models, is its capability to perform a consequence analysis as a subroutine. The subroutine consists of a statistical method for predicting potential fatalities (or other acute responses) from the concentration distribution of the toxic plume or cloud. The statistical subroutine was introduced in a previous paper [1] and was originally applied in a steady-state Gaussian neutral buoyancy dispersion model. The subroutine has now been incorporated into ACTOR which is a negative/neutral buoyancy model, both steady-state and instantaneous.

For quantifying consequence analysis, it is necessary to define a minimum lethal acute toxicity concentration (ATC) for a given substance. Although several similar definitions exist (e.g., the EEGL, the EEPG, and the ERPG [2]), in ACTOR the ATC is defined as the lowest reported $LC_{50}/10$ for any mammalian species tested up to eight hours, or if lower yet, the lowest LC_{lo} or the IDLH. The ATC must be greater than the TLV or the STEL for that substance. [1,3]

The concept of the ATC is key to the entire process. The ATC becomes the border or isopleth of a toxic cloud or plume, and higher concentrations within the cloud can be identified in terms of multiples of the ATC, forming a series of bands of increasing toxicity. Figure 1 shows a plot of such a cloud beyond the property line ADB, as obtained from atmospheric dispersion modeling for a given release quantity and release scenario. Each toxicity band can be statistically related to a given probability of fatalities, according to the normal cumulative exponential distribution function (mortality curve). [Figure 2] The median lethal concentration is assumed to be the same for a normal heterogeneous population distribution as it is for the homogeneous animal test population upon which the ATC is based.

For purposes of modeling, the ATC has been defined as the concentration that has a probability of causing 6.7% fatalities among the exposed population. This value is computed from one-tenth of the median lethal concentration from the mortality curve. The multiple-ATC levels are also related to percent fatalities, and the modeled plume is superimposed on a detailed site and community map. The total number of potential fatalities within the plume can then be predicted, once the number of exposed persons within each toxicity band is determined or estimated.

In many accidental release scenarios, the exposure time of a receptor is significantly different from the actual animal test duration upon which the ATC is based. For example, a cloud of toxic gas may pass over a population within minutes. If the ATC test time for the substance is one hour, that concentration may not be high enough to result in a fatality if the exposure time is only a few minutes. In these cases, we would use a time correction factor, usually Haber's rule as referenced by MacFarland [4]. We have found that Haber's rule is reasonably accurate at intermediate durations from a few minutes to a few hours. At the very low end (e.g., one minute) Haber's rule tends to overpredict, and at the high end (e.g., 8 hours), Haber's rule tends to underpredict. Some attempts are now being made to develop more accurate correction factors on a case by case basis. These would be empirical equations of the form ct^n = constant, instead of the Haber's rule of the form ct = constant.

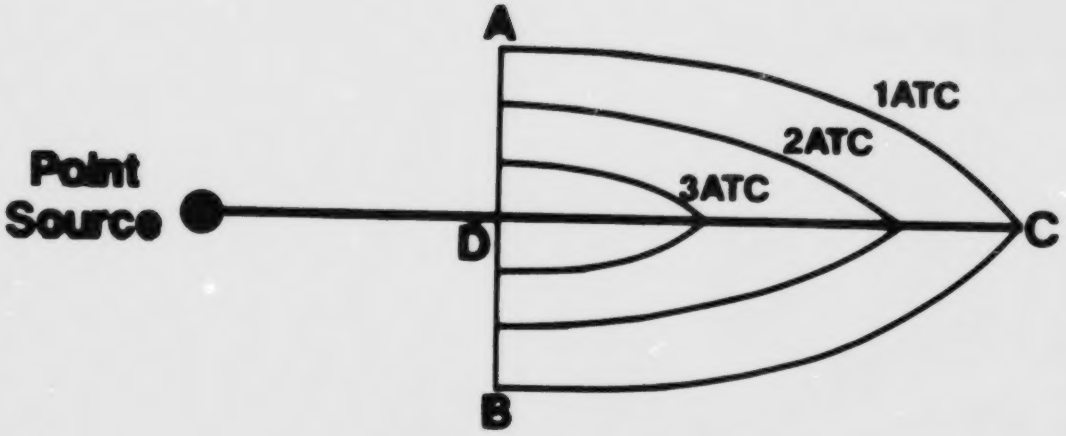
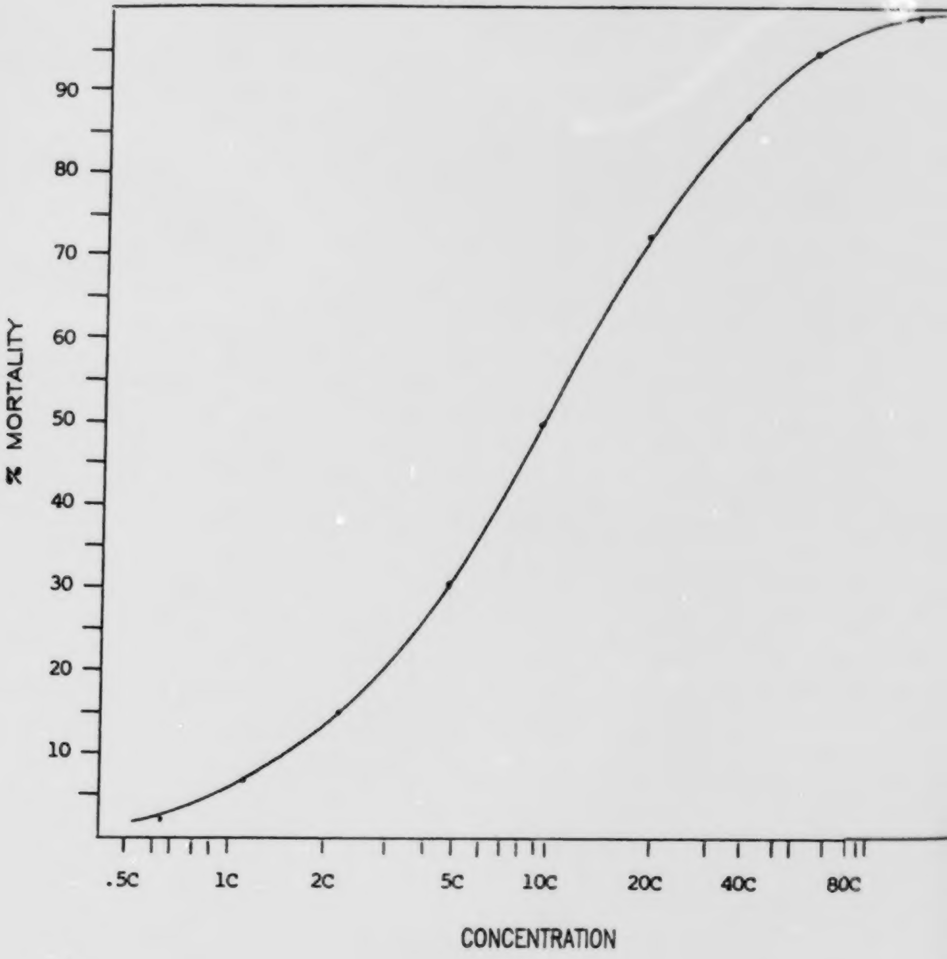

A
1ATC
2ATC
Point
Source
3ATC
D
C
B

Figure 1: Bands corresponding to various multiples of the ATC.

Figure 2. CONCENTRATION VS. MORTALITY PLOT



Applications of the ACTOR Model

The ACTOR model has general applications in accident prevention and in emergency response planning, and is also a useful research tool to study factors of greatest concern in either of these categories.

The main intent of the model is to assist in the process of accident prevention by providing the capability to perform acute risk assessments of specific pieces of equipment. A complete risk assessment takes into account both consequences and frequency or probability of an accident occurring. ACTOR will provide the best estimate of the potential number of fatalities for a particular release scenario. When this estimate is combined with the frequency or probability estimate, a measure of risk is obtained. Risk is usually expressed as the number of fatalities predicted per year. Each specific piece of equipment is then evaluated to determine if the risk meets acceptable standards.

The model is also useful in the planning stages of emergency response for estimating evacuation distances. Accuracy in the evacuation radius of concern is important since underprediction is unsafe and overprediction needlessly disrupts the community. In addition to simple prediction of the evacuation area, more detailed consequence analysis may be required in specific areas of sensitivity, such as hospitals, schools and nursing homes. Special consideration should be made in establishing evacuation needs for these areas.

In both applications of accident preventon and emergency response planning, the ACTOR model can be used beyond obtaining a level of risk or an evacuation radius. The model provides detailed means to evaluate various control strategies or operating alternatives to reduce risk. Site-specific studies of numerous other variables can be systematically conducted. Examples of such studies are as follows:

- Comparison of present products with substitution products under various release scenarios.

- Studies of release dilution percentages from vented containment structures.

- Evacuation strategy comparisons under typical site-specific meterological variables such as atmospheric stability, wind speed, wind direction, and surface roughness of surrounding terrain.

- Investigation of natural barriers and other means of increasing surface roughness to enhance toxic cloud dispersion.

- Studies of equipment location within a site to minimize impact on off-site populations.

- Evaluation of variations in buffer zones around sites to minimize impact on off-site populations.

Studies of this nature demonstrate the usefulness of the ACTOR model for communities and toxic chemical facilities in reducing accident risk.

Model Description

ACTOR may be classified as a box or slab model, which characterizes the lateral spreading of a heavier-than-air gas due to gravity and density of the substance. The gravity spreading or slumping in a box model continues until the plume is diluted enough, by the entrainment of air, to become neutrally-buoyant.

ACTOR incorporates van Ulden's equations [5] modified by Raj [6] for continuous releases, and the air entrainment rate equation from Zeman and Tennekes [7]. The transition from negative to neutral buoyancy is determined from van Ulden's assumptions [5]. At transition the model changes over to a neutral buoyancy Gaussian model with the plume as a volume source. The steady-state model assumes surface roughness values from the Engineering Sciences Data Unit published by

Davies and Singh [8] and the Smith corrections to Briggs' rural equations [9].

For instantaneous releases, the Zeman and Tennekes [7] entrainment rate assumptions are used, and in the Gaussian phase, dispersion is characterized by Slade coefficients [10].

At given downwind distances, the concentrations are computed using the so-called "top hat" distribution equations [11].

At present, ACTOR is used for ground-level releases as well as elevated releases but does not have the capability of computing the source term, that is, emission rate and duration for various scenarios. However, it does incorporate an algorithm for computing the instantaneous flash fraction from the release of liquified gases, and the effective molecular weight of such releases. The unflashed fraction disperses as a steady-state dense gas.

The program is written in LOTUS 123, and may be used in the spreadsheet or menu-driven mode. A sample printout for the ACTOR model is given in the Appendix.

Prediction of the Downwind Extent of the High Consequence Dense-Plume Region

If a steady-state plume of gas or vapor exhibits heavier-than-air behavior, it will slump and stay close to the ground for some distance depending upon the wind speed and numerous other factors. Potential consequences are considerably more severe in this region before the transition to neutral buoyancy occurs. For preliminary consequence analysis, it is informative to estimate at least the downwind extent of this region. For the complete analysis, ACTOR computes all coordinates of the width and height of the dense plume region based on the van Ulden/Raj equations and assumptions for plume growth. However, for computation of the downwind extent of the dense plume region to the transition point, ACTOR incorporates a unique deriviation of the van Ulden equation for transition distance. The equation is easy to use with a hand calculator in preliminary consequence analysis to estimate the downwind extent of the high-consequence region.

The equation for transition distance x_t (m) is as follows:

$$x_t = (311.82/u^3)\ (m_e/Mw)\ [(Mw/28.9)-1]\ \ln\ (Z/Zo)^3$$

where u is wind speed (m/s)

z is the wind speed measurement height (m)

m_e is the mass emission rate (kg/s)

Mw is the molecular weight of the substance

Z_o is the surface roughness of the terrain(m)

The surface roughness Z_o is a parameter equal to approximately one-tenth of the actual height of surface obstructions. Table 1 should be used to select an appropriate surface roughness for a given site.

Table 1 - Surface roughness/terrain description

Surface roughness Range(m)			
0.008	-	0.02	Short grass (0.1-0.2m); few trees (wintertime)
0.03	-	0.07	Long grass (0.3-0.7m); crops; flat paved areas (e.g., airport runways); few trees (summertime)
0.1	-	0.3	Many trees, hedges, few buildings

(Source: Davies and Singh [8])

Validation

ACTOR predictions have been compared with test data obtained from Desert Tortoise [12] and from Maplin Sands, Thorney Island, Coyote and Welker trails [13]. Good to excellent agreement is obtained with mean centerline concentrations. Very good agreement was obtained between the ACTOR prediction and actual plume width measured for Desert Tortoise Test #4. Results are given in the Appendix Tables 1 and 2 and Figures 1 through 4.

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Appendix

Model Validation

Table 1 - Instantaneous Release

Test: Thorney Island 15

Substance: Freon 12 (Nitrogen mixture)

Volumetric Release Rate: 2100 m^3

Wind speed: 5.4 m/s @ 10m

Surface Roughness: 0.01m

Stability: D

Downwind	Centerline Concentrations (Mole %)	
Distance(m)	Measured	ACTOR
50	25.0	21.0
100	12.5	11.0
200	4.4	4.0
300	2.4	2.1
400	1.5	1.3
500	0.6	0.8
750	0.3	0.4

Appendix

Model Validation

Table 2 - Continuous Release

Test: Desert Tortoise 4

Substance: Ammonia (liquified)

Release Rate: 108 kg/s

Wind Speed: 4.5 m/s @ 4m (avg.)

Surface Roughness: 0.005m

Stability: E

Downwind	Centerline Concentrations (Mole %)	
Distance(m)	Measured	ACTOR
100	6.5	15.0
800	2.1	2.1
2800	0.5	0.9
Plume width(m) @ 800m (0.2% level)	400	379 (slab width)

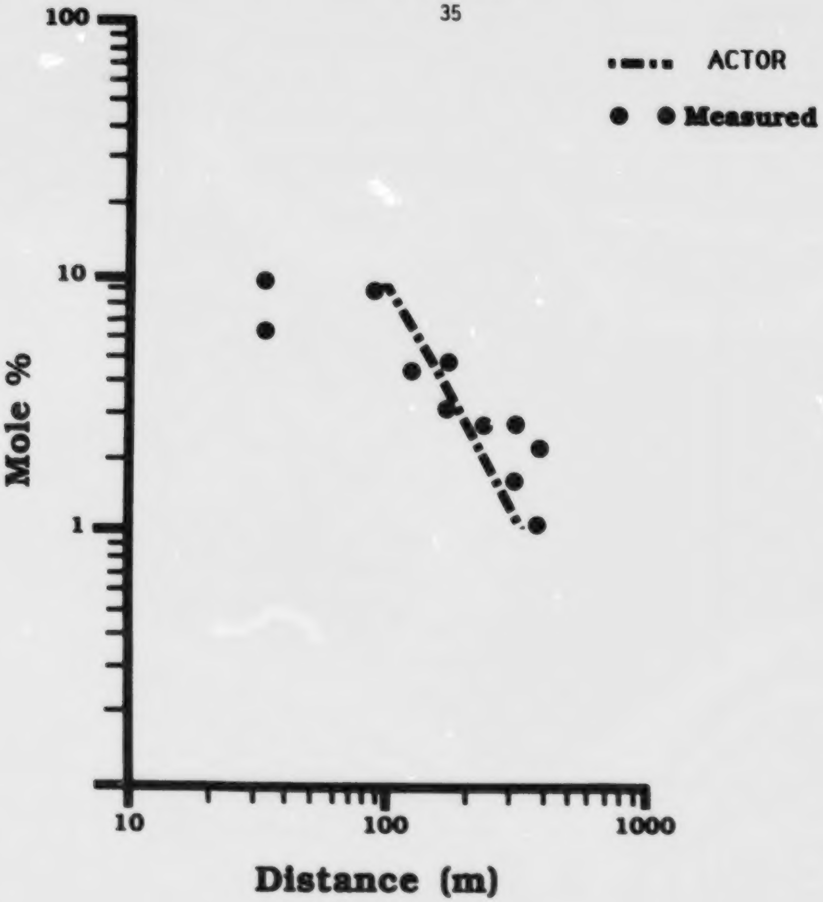


Figure 1 Centerline Concentrations (Measured vs. Predicted)

Test: Maplin 47 (Continuous)
Substance: Propane (MW = 44)
Release Rate: 136.2 x 10^3 kg/h
Wind Speed: 5.8 m/s @ 10 m
Surface Roughness: 0.00034 m
Stability: D
Volumetric Release Rate: 15.8 m^3/s

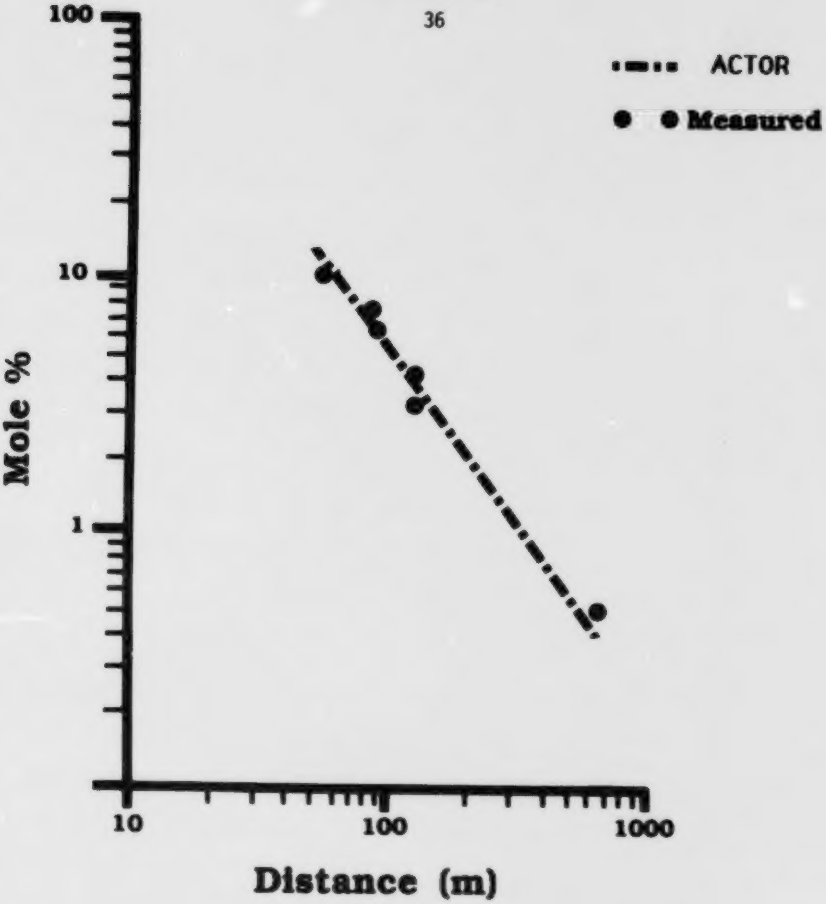


Figure 2 Centerline Concentrations (Measured vs. Predicted)

Test: Maplin 50 (Continuous)
Substance: Propane (MW = 44)
Release Rate: 150 x 10^3 kg/h
Wind Speed: 7.9 m/s @ 10 m
Surface Roughness: 0.00034 m
Stability: D
Volumetric Release Rate: 17.4 m^3/s

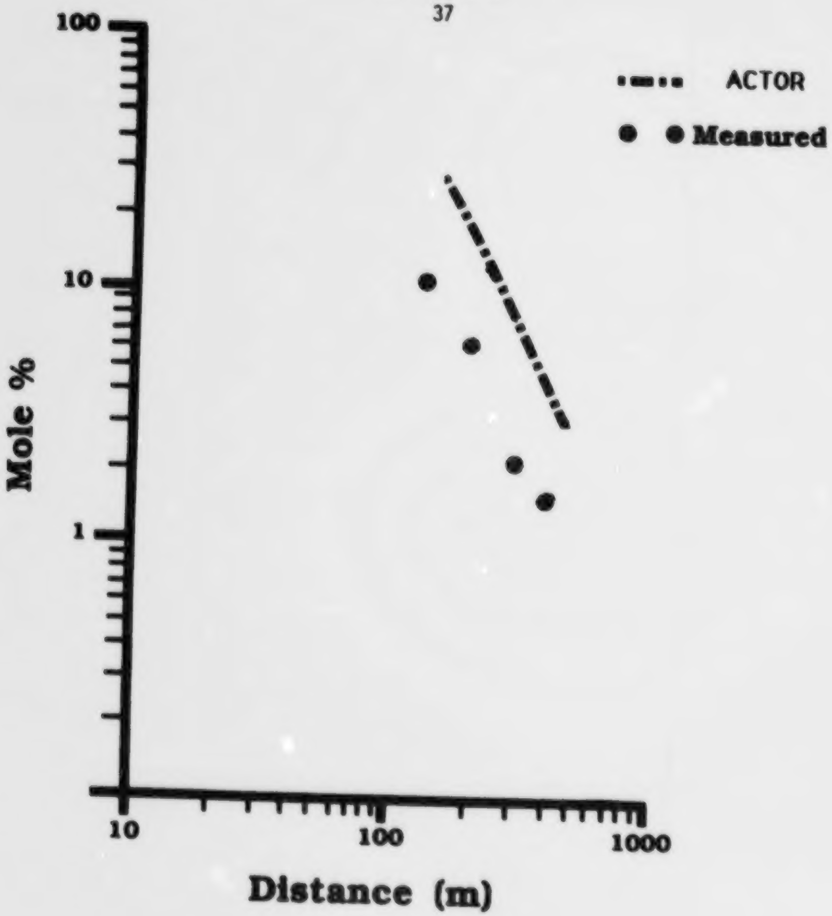


Figure 3 Centerline Concentrations (Measured vs. Predicted)

Test: Coyote 6 (Continuous - 82 s)
Substance: LNG (MW = 43.3)
Release Rate: 424.8 x 10^3 kg/h
Wind Speed: 5.9 m/s @ 3.0 m
Surface Roughness: 0.0002 m
Stability: D
Volumetric Release Rate: 65.8 m^3/s

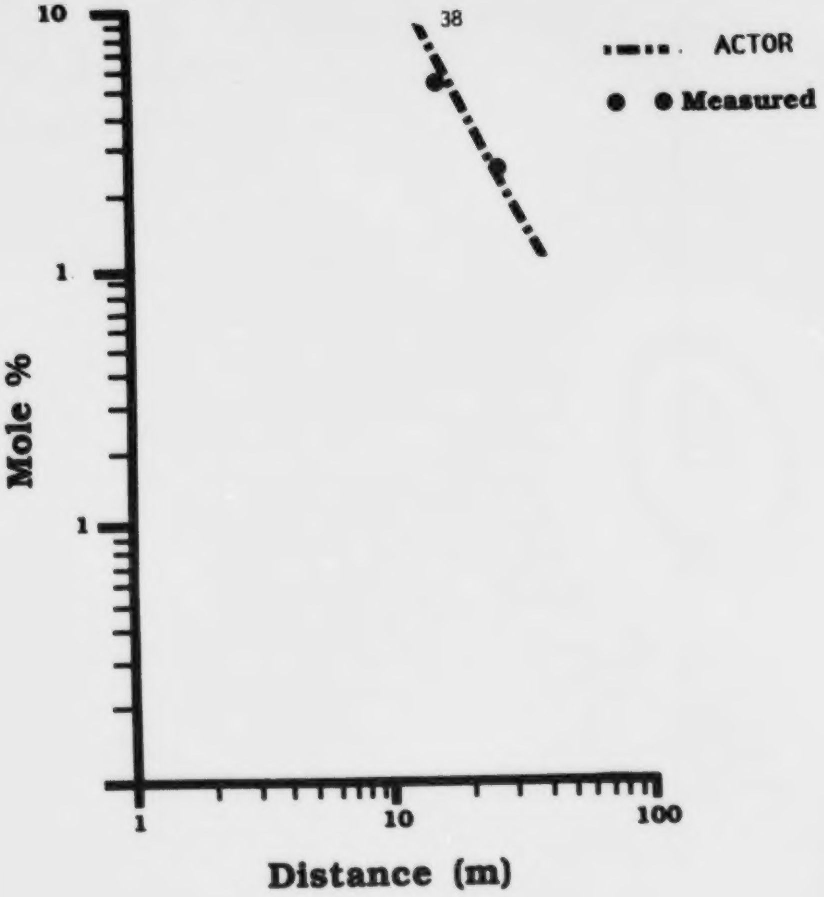
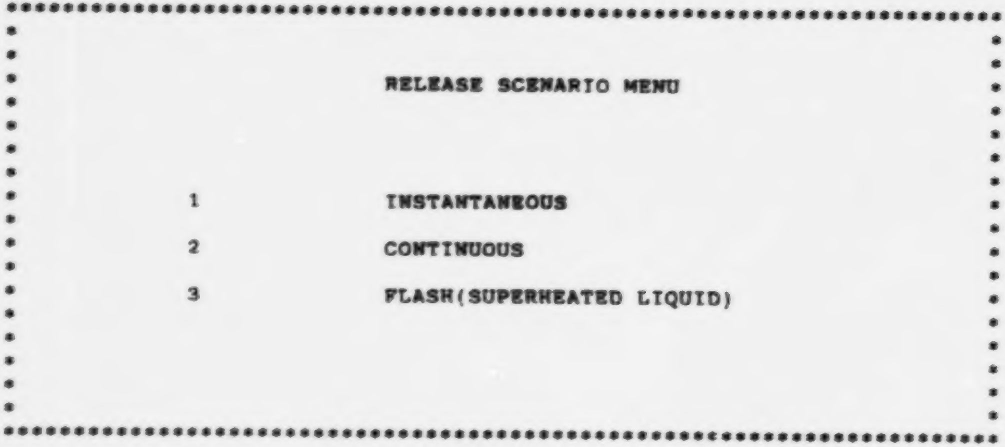


Figure 4 Centerline Concentrations (Measured vs. Predicted)

Test: Welker 334-2 (Continuous)
Substance: Propane (MW = 44)
Release Rate: 1984 kg/h
Wind Speed: 2.77 m/s @ 2.44 m
Surface Roughness: 0.01 m
Stability: C
Volumetric Release Rate: 0.23 m^3/s

APPENDIX

```
**********************************************************************
*                 A C T O R   O U T P U T                            *
*                                                                    *
*                          MAIN MENU                                 *
*                                                                    *
*            1             RELEASE SCENARIO MENU                     *
*                                                                    *
*            2             METEOROLOGICAL MENU                       *
*                                                                    *
*            3             DISPERSION ANALYSIS MENU                  *
*                                                                    *
*            4             CONSEQUENCE ANALYSIS MENU                 *
*                                                                    *
*            5             RESULTS MENU                              *
*                                                                    *
*            6             QUIT MENU                                 *
*                                                                    *
*                                                                    *
**********************************************************************
```



```
************************************************************
*                                                          *
*                                                          *
*                   RELEASE SCENARIO MENU                  *
*                                                          *
*                                                          *
*                                                          *
*                                                          *
*        1          INSTANTANEOUS                          *
*                                                          *
*        2          CONTINUOUS                             *
*                                                          *
*        3          FLASH(SUPERHEATED LIQUID)              *
*                                                          *
*                                                          *
*                                                          *
*                                                          *
************************************************************
```

```
****************************************************************
*                                                              *
*          DISPERSION ANALYSIS INPUT MENU                      *
*                                                              *
*   1  DATE OF THIS ANALYSIS:                   MAY 1, 1990    *
*                                                              *
*   2  SUBSTANCE NAME:                          ACETALDEHYDE   *
*                                                              *
*   3  MODEL OPTIONS(GAUSSIAN=1,DENSE/GAUSSIAN=2)          2   *
*                                                              *
*   4  INCREMENT OF DOWNWIND DISTANCE(M)                 100   *
*                                                              *
*   5  SOURCE DISTANCE TO PROPERTY LINE(M)               100   *
*                                                              *
*   6  INITIAL PERCENT CONCENTRATION                     100   *
*                                                              *
*   7  CONCENTRATION MEASUREMENT HEIGHT(M)                 1   *
*                                                              *
****************************************************************
```

```
***********************************************************************
*                                                                     *
*                                                                     *
*                CONTINUOUS RELEASE INPUT MENU                        *
*                                                                     *
*                                                                     *
*           1    MASS RELEASE RATE(KG/S)              0.617944        *
*                                                                     *
*           2    MOLECULAR WEIGHT                           44        *
*                                                                     *
*           3    RELEASE TEMPERATURE(K)                    293        *
*                                                                     *
*           4    VAPOR PRESSURE AT RELEASE TEMP.(mmHg)     750        *
*                                                                     *
*           5    RELEASE OR STACK HEIGHT(M)                  0        *
*                                                                     *
*           6    STACK DIAMETER(M)                           0        *
*                                                                     *
***********************************************************************
```

```
**********************************************************************
*                                                                    *
*                  METEOROLOGICAL INPUT MENU                         *
*                                                                    *
*                                                                    *
*                                                                    *
*   1   ATMOSPHERIC STABILITY(A=1,B=2,C=3,D=4,E=5,F=6)      6        *
*                                                                    *
*   2   SURFACE ROUGHNESS(M)                            0.001        *
*                                                                    *
*   3   WIND VELOCITY(M/S)                                  2        *
*                                                                    *
*   4   WIND VELOCITY MEASUREMENT HEIGHT(M)                10        *
*                                                                    *
*   5   FRICTION VELOCITY(M/S),DEFAULT=0                    0        *
*                                                                    *
*   6   AMBIENT TEMPERATURE(K)                            293        *
*                                                                    *
**********************************************************************
```

```
*************************************************************************
*                                                                       *
*            TOXICITY  EFFECTS INPUT MENU                               *
*                                                                       *
*                                                                       *
*       1    ACUTE TOXICITY CONCENTRATION,ATC,(G/M^3)     0.2745        *
*                                                                       *
*       2    TOXICITY TEST DURATION(HR),DEFAULT=0              0        *
*                                                                       *
*       3    EXPOSURE TIME(MIN),DEFAULT=0                      0        *
*                                                                       *
*                                                                       *
*                                                                       *
*                                                                       *
*                                                                       *
*                                                                       *
*            DEFAULT MEANS THAT HABER'S RULE IS NOT USED                *
*                                                                       *
*************************************************************************
```

```
**************************************************************************
*              POPULATION DISTRIBUTION INPUT MENU                        *
*       (INPUT EITHER POPULATION DENSITY OR NUMBER OF PEOPLE)            *
*                                                                        *
*  1    POPULATION DENSITY(NUMBER OF PEOPLE PER SQUARE MILE)  10000      *
*                                                                        *
*  2    NUMBER OF PEOPLE WITHIN 1 & 2 ATC ISOPLETH                0      *
*                                                                        *
*  3    NUMBER OF PEOPLE WITHIN 2 & 3 ATC ISOPLETH                0      *
*                                                                        *
*  4    NUMBER OF PEOPLE WITHIN 3 & 4 ATC ISOPLETH                0      *
*                                                                        *
*  5    NUMBER OF PEOPLE WITHIN 4 & 5 ATC ISOPLETH                0      *
*                                                                        *
*  6    NUMBER OF PEOPLE WITHIN 5 & 10 ATC ISOPLETH               0      *
*                                                                        *
*  7    NUMBER OF PEOPLE WITHIN 10 & 50 ATC ISOPLETH              0      *
*                                                                        *
*  8    NUMBER OF PEOPLE WITHIN 50 & 100 ATC ISOPLETH             0      *
**************************************************************************
```

```
                  A C T O R   R E S U L T S
Release amount in pounds per hour                                4900
Release Richardson number                                         530
Maximum distance for an ATC isopleth(m)                          3200
Transition from neg. to neutral buoyancy(m)                       223
Plume touchdown(m)                                                  0
Plume touchdown concentration(g/m^3)                                0
Fraction of the liquid vaporized                               :  1.00
Area of negative buoyancy phase(m^2)                             7031
Area of neutral buoyancy phase(m^2)                            252400
Total area of one ATC or more isopleth(m^2)                    259431
Number of people affected by the plume                        1002.10
Fatalities during neutral buoyancy phase                       184.55
Fatalities during negative buoyancy phase                       27.15
Fatalities during both phases                                  211.70
Analysis is completed
-----------------------------------------------------------------
 X(m) Ybox(m)Y(ATC) Y(2ATC)Y(3ATC)Y(4ATC)Y(5ATC)       Cc
-----------------------------------------------------------------
    0 0.2164       0       0       0       0       0 1805.931
  100 33.686       0       0       0       0       0 45.49815
  200 53.465       0       0       0       0       0 28.93299
  300 70.055  41.606  37.603  35.051  33.120  31.542 12.08230
  400 84.863  51.589  45.902  42.221  39.402  37.068 7.647719
  500 98.473  60.495  52.963  48.012  44.164  40.932 5.341822
  600 111.19  68.472  58.930  52.551  47.508  43.194 3.976604
  700 123.23  75.619  63.892  55.903  49.459  43.812 3.095386
  800 134.70  82.008  67.907  58.093  49.975  42.626 2.490317
  900 145.70  87.694  71.010  59.106  48.934  39.270 2.055102
 1000 156.31  92.718  73.215  58.883  46.087  32.896 1.730509
 1100 166.56  97.112  74.517  57.310  40.927  20.657 1.481280
 1200 176.51  100.89  74.896  54.182  32.228       0 1.285303
 1300 186.18  104.09  74.307  49.121  14.399       0 1.128102
 1400 195.61  106.71  72.674  41.346       0       0 0.999857
 1500 204.82  108.76  69.880  28.634       0       0 0.893710
 1600 213.82  110.24  65.736       0       0       0 0.804739
 1700 222.64  111.15  59.927       0       0       0 0.729339
 1800 231.29  111.48  51.860       0       0       0 0.664816
 1900 239.78  111.22  40.159       0       0       0 0.609119
 2000 248.12  110.34  18.935       0       0       0 0.560666
 2100 256.32  108.83       0       0       0       0 0.518221
 2200 264.40  106.62       0       0       0       0 0.480800
 2300 272.35  103.69       0       0       0       0 0.447620
 2400 280.19  99.938       0       0       0       0 0.418045
 2500 287.92  95.269       0       0       0       0 0.391554
 2600 295.54  89.532       0       0       0       0 0.367722
 2700 303.07  82.498       0       0       0       0 0.346192
 2800 310.51  73.790       0       0       0       0 0.326669
 2900 317.86  62.709       0       0       0       0 0.308902
 3000 325.13  47.623       0       0       0       0 0.292680
 3100 332.31  21.239       0       0       0       0 0.277824
 3200 339.42       0       0       0       0       0 0.264180

          X=Downwind distance(m)
          Y=Plume or cloud width(m)
          Cc=centerline concentration(g/m^3)
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EXPERIMENTAL STUDY OF CHEMICAL BEHAVIOUR AT SEA : POLLUTMAR I AND II TRIALS

by

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SUMMARY

In order to better understand the physico-chemical behaviour of chemicals when accidentally released at sea, two sea trials were conducted by CEDRE during 1989.

During the first series of trials off Brittany (POLLUTMAR I), 3 tons of chemicals were released (ethyl-2 hexanol, butyl methacrylate, acetone, ethylene glycol) and the diffusion of the chemicals in air and within the water column was observed and measured.

During the second series of trials in the Mediterranean sea (POLLUTMAR II), a gas tracer, sulfur hexafluoride, was released just above sea level and was followed and observed for several kilometers.

These two trials allowed us to compare the result predicted by forecast models with those obtained from "in situ" measurements.

INTRODUCTION

Chemical spill response at sea requires a good understanding of the chemical's behaviour in sea water.

Up to now, our knowledge of the physico-chemical behaviour of chemicals accidentally spilled have been based on laboratory tests, in tanks, or in a "controled natural environment".

The first objective of the two "POLLUTMAR" trials which were undertaken by CEDRE in 1989 was to better define the behaviour of chemicals (spreading, dispersion in water, and in air) under conditions which are more realistic ; the second objective was to validate results provided by risk assessment prediction models.

Two sea trials took place with surface ship and air craft:

- "POLLUTMAR I" July 3-6, 1989, off the coast of Brest, where a total of approximately 3 tons of chemicals were released (ethyl-2 hexanol, butyl methacrylate, acetone, ethylene glycol),
- "POLLUTMAR II" October 23-25, 1989, off the coast of Toulon, in the Mediterranean, where a gas tracer (sulfur hexafluoride) was released and followed for several kilometers.

I. POLLUTMAR I TRIALS

I.1. Description of the trials

During these series of trials the chemicals, chosen among those most often transported and representative of the different behaviour families, were released at sea. Quantities of 200 and 400 liters of each of the 4 chemicals were released.

The characteristics of the chemicals are presented in table 1.

Table 1

Chemical characteristics

Characteristics Chemical	European classification	Density		Solubility	Vapor pressure AMB.T.	Dye
		Liq.	Vap/air			
Ethyl-2 hexanol	FD	0.834	5.790	0.1	0.024	RED ORGANOL
N-Butyl methacrylate	FED	0.8975	6.192	0.6	0.53	RED ORGANOL
Acetone	DE	0.791	2.58	78	24.75	BLACK SAVINYL
Ethylene glycol*	SD	1.115	2.761	All	0.008	PINK SAVINYL

* During the trials, the chemical was used in a 30% solution in fresh water to obtain a density of 1.03.

Dyes which are specific for use with the chemicals and which are insoluble in water (see Table 1) were pre-mixed with the chemicals in amounts equal to 10g/l (mixing occured before release). The slicks were also marked using buoys.

A certain number of water sample analyses were made on board (using colorimetry and infra red spectrometry) ; additional analyses were done in a laboratory after the trials were completed (using Gas Chromatography). Measurements of organic vapor in air were made using an HNU photoionizer. An oceanographic and meteorological station continually recorded the following parameters : surface current, subsurface current (down to 10 m), temperature, salinity, swell (height and direction), wind (speed and direction).

The slicks were also photographed and filmed from aircraft. In addition, we also attempted to use sensing techniques with the aircraft of the French customs authority which is specifically equipped for this job.

During the trials, several prediction models (CHEMSPIL, HACS, EFFECTS, EXAMS) were run in order to determine :

- the slick's spreading,
- chemical evaporation and dispersion in air,
- dissolution and dispersion in the water column.

I.2. Main results

a) Remote sensing

These flights enabled the following conclusions :

- no detection was possible using side SCAN radar,
- the presence of ethyl-2 hexanol and n-butyl methacrylate was detected using an infra-red scanner, but the presence of acetone was not determined (tests using the infra-red scanner to detect ethylene glycol were not made),
- the best results in remote sensing detection were obtained in the trials involving the methacrylate with a flight at 500 feet (the surface which can be swept is larger at 1 000 feets but results are less precise), and even these results are significantly poorer than those obtained for a test slick of diesel fuel.

Results obtained during the sea trials suggest the possibility of dectection using an infra-red scanner for floating chemical slicks. On the other hand, an absence of detection for the acetone is logical since this very soluble chemical rapidly disappeared from the surface.

Even if the results obtained are poorer than those for oil slicks, they can still be interpreted and enable us to detect the presence of chemical slicks as well as determine the varying thicknesses of a slick.

However, we still have questions concerning the influence of the chemical dyes which were mixed with the test chemicals before they were released. It is advisable to conduct trials using non-dyed floating chemicals.

b) Prediction models

On the whole, the predictions obtained using the various models are very similar : all agree that the four chemicals should be totally dispersed within the water and/or evaporated and dispersed in the air several minutes after release.

c) Comparison of field measurements and prediction models

The predictions provided by the various models differ from the "in situ" observations during the trials. The differences concern the following points :

- persistance of the slick on the water surface (ethyl-2 hexanol and N-butyl methacrylate
The "in-situ" observations and measurements have shown that the slick persists for a longer time period than was predicted since when the observation period was terminated (after 30 minutes or 1 hour according to the case), the slick or patches of slick were still present. The slick of ethyl-2 hexanol was probably persistant for several hours ; since no longer observation time had not been scheduled during the trials, it is difficult to estimate the actual length of time the slicks remained on the surface.
This persistance of surface slicks shows that the kinetics of dissolution for chemicals in the water mass as well as the kinetics of evaporation are longer than predicted.

- Diffusion of chemicals in water
In the same manner, the kinetics of a diffusion of chemicals in water are slower than predicted by the models.

* for ethyl-2 hexanol (solubility 0.1%), the dispersion in water was much slower than what the models predicted which was that the amounts of ethyl hexanol should rapidly decrease to an amount much lower than 1 ppm 10 minutes after the initial release. In fact, after the initial release, the chemical concentrations were about 10 ppm under the slick but they remained persistant (< 1 ppm) during the entire observation period (30 minutes) which shows the slow dissolution of the slick from the water surface.

* for n-butyl methacrylate (solubility 0.6%), the dispersion in water was also slower than what was predicted by the models ; the models estimated that all the n-butyl methacrylate would be dispersed in the water mass after 3 minutes, however the detectable amounts were again on the order of 1 ppm 30 minutes after release, with a maximum of more than 10 ppm.

* For acetone (78% solubility) the prediction models estimated that the release would dissolve very rapidly and provide zero concentration levels after 3 minutes. However, the results of the water analyses revealed that the concentrations of acetone were as high as 4 ppm (in the water level between 0-4 m deep) 15 minutes after release with a maximum of 30 ppm just below the slick surface.
As was the case for the two previous chemicals (floaters), the actual process of diffusion is slower than what was predicted.

* For ethylene glycol (total solubility, heavier than water), the models predicted that the concentration of ethylene glycol would rapidly diminish and zero concentrations in the water mass would be obtained within 2 minutes.
The trials have shown that after 15 minutes the concentrations varied between 0 and 100 ppm and at the conclusion of the observation period (30 minutes), the concentrations were still at approximately 40 ppm.
It should be remembered that this chemical was pre-diluted in fresh water in order to obtain a density which is the same as sea water, and this has probably modified the chemical's expected behaviour.

- Diffusion of chemicals in air

The results obtained have shown that the concentrations above the slick are very low for ethyl-2 hexanol (maximum concentration of 6 ppm just above the slick). For the butyl methacrylate, the maximum concentration of vapor above the slick is higher : a value of 70 ppm was recorded just after the release, which is normal in light of the higher evaporation rate for the chemical (vapor pressure 0.5 kPa for butyl methacrylate, classification FED, while ethyl-2 hexanol is considered as a floater and dissolver, FD).

However, the amounts of concentration in air are much lower than those predicted by the models, which were on the order of thousands of ppm (that is, on the order of 1 part/thousand) during several seconds or minutes following the release. In fact, the recorded concentrations are much lower (about 100 times lower), however the vapors persists for a longer time, apparently for the length of time that the slick is present on the water surface. The kinetics of a disappearance of these chemicals in air have shown a slow evaporation which may also explain the slicks persistance on the water surface.

The results observed for acetone or ethylene glycol are similar to what was observed for the two chemicals : the concentrations observed in the field (less than 5 ppm) are much lower than what was predicted by the HACS (Hazard Assessment Computer System) model immediately after release.

I.3. CONCLUSION OF "POLLUTMAR I" SEA TRIAL

The differences observed between the predictions proposed by mathematical models and the actual field observations are as follows :

- the phenomena of evaporation and spreading are slower than what was predicted by the models ;
- the concentrations of chemicals in the water are lower than what was predicted.

From an operational point of view, this confirms the fact that :

- chemicals, even those considered to be evaporators or dissolvers, could persist for a long period on the water surface. This may justify using pollution response methods which might at first be limited by an absence of color for most chemicals,

- the models can be perfected and should be used with caution until they have been improved,

- remote sensing seems to give interesting results in some cases.

II. POLLUTMAR II TRIALS

This series of trials had the objective of :

- studying the dispersion of a gas cloud above the sea surface by releasing a non-toxic gas tracer : sulfur hexafluoride (SF6),

- to compare observations in the field with the predictions of several mathematical models.

II.1. Description of the trials

A spray system was installed at the rear of a ship and puffs of a gas tracer were released at various intervals. Previously positioned surface craft recorded gas concentration at the surface and about 10 meters above the water (measured using gas phase chromatography).

- Installing the system

The spray system was intended to simulate the evaporation of a chemical from a chemical slick about 150 m in diameter ; in order to install such a set up, several anchored buoys were necessary as well as about 1000 m of hose, twenty spray heads, several bottles of gas tracer and a compressor.

- Trials

Several trials took place with various release rates in order to simulate the evaporation of chemicals which are more or less volatile. The gas tracer was measured up to a distance of 4 km down wind using 3 small sea crafts (zodiacs), one of which was equipped with a system for measuring at a low altitude. Two additional trials took place in order to simulate the movement of a gas cloud. The non-toxic tracer was captured in a 10 m long plastic bag which was then pierced and the pre-positioned surface crafts were able to observe the cloud's subsequent movement.

- Measuring different parameters

During the trials, the meteorological factors were measured by a weather station and positioning the surface craft for taking measurements was assisted by use of the radar on board the support ship.

II.2. Main results

The three main conclusions of this study are as follows :

- the diffusion of gas at sea is slower than that predicted by the models (and is also slower than what we observe on land) due to the absence of air turbulence caused by terrestrial relief,

- since meteorological conditions are relatively variable at sea, it is difficult to correctly predict the evolution of a toxic plume since the plume will coil and twist at the water surface,

- due to the lack of wind stability and to the lack of air turbulence, the gas cloud is observed as being larger (40°) and four times more extensive (spread out) than the value predicted by the models.

In fact, atmospheric diffusion is a function of a certain number of parameters, notably wind speed and direction, but also turbulence which could enhance a chemical's dispersion. On land, turbulence is caused by relief (trees, buildings, mountains). If we study atmospheric dispersion at sea, we are dealing with a flat surface that is devoid of relief which could result in supplementary turbulence. Thus, the diffusion of a pollutant is slower at sea since there is less mixing. This fact could explain the gap between the measured concentrations and those predicted by the models. In fact, at a given moment and at a given point, with less turbulence, there will be less diffusion of a pollutant and therefore a more homogeneous plume with a consequently higher chemical concentration.

In order to take into consideration this lack of turbulence, it is necessary to modify the mathematical formulas in order to correct the factor 4 which was exprimentally proposed as compensation between the measured value and the predicted value.

The differences between diffusion at sea and on land can be summarized in the following table :

Table 2

	Diffusion at sea	Diffusion on land
Wind direction	Very variable 40° angle	In function of wind speed 60°, 40°, 30° and 20° angles
Turbulence	Poor	Significant

ACKNOWLEDGEMENTS

We would like to thank the French Navy, the Ministry of the Environment, and the Interministerial Mission of the Sea for their financial assistance.

We are very grateful to the French Navy for the support ship and surface crafts, to the French customs Authority for the use of their remote sensing air craft, to the Warren Spring Laboratory (U.K.) for their participation to the trial with a photoionizer and to the Centre d'Etudes Nucléaire de Grenoble and the Securité Civile for their technical assistance and modelling.

A Source Strength Model For Accidental Release of Hazardous Substances

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ABSTRACT

The emission rate (or source strength) of accidentally released chemical is evaluated in terms of gas/vapour emission into the atmosphere by using a comprehensive model. The model in a step wise fashion calculates mass flow leak rate from a ruptured container to the eventual stage of gas/vapour emission to the atmosphere. The equations for discharge of gas or liquid, flash vapourization and evaporation from liquid pool are from well known literature articles. The special advantages of this model are its automatic linkage with the chemical and real time weather data bases and also its relative user-friendliness. The model is simple and yet applicable for a wide range of accident scenarios. Further it is unique in a way, it directs the user to the specific dispersion model for a given accident type. namely Heavy Gas Puff (or plume) dispersion model or a Neutral Gas Plume (or puff) dispersion model as applicable case may be of our Air Quality Package of Programs (AQPAC) for accidental response.

1. INTRODUCTION

An Air Quality Package of programs (AQPAC) was developed (Daggupaty, 1988) to assist meteorologists of the Atmospheric Environment Service (AES) at regional weather centres across Canada in response to accidental releases of hazardous chemicals into the atmosphere. The computer programs are written in an interactive, user friendly mode for use on the regional AES minicomputers. The package contains a source strength model, chemical information and a set of numerical models to estimate transport and dispersion of buoyant, neutral, and heavy gases in case of an accidental release into the atmosphere.

The source strength calculation model of the package is of special importance to the overall response mechanism. The area of the hazardous zone predicted by the dispersion model is critically dependent on the amount of material that has accidentally entered the atmosphere. The emission rate (source strength) is likely to be unknown in the early stages of most accidents. Thus this model is developed to provide the first estimate of the quantity of the chemical spilled into the environment. The model is capable of responding to several types of accidental leaks. For instance the contents may be gaseous or liquid; the type of release may be continuous or instantaneous; and the rupture may be above or below the liquid level in the container. The containers may be pressurized, refrigerated, or at ambient conditions; they may be transportation tankers, pipelines or storage vessels. In the case of rupture to liquid containers the final physical processes of flash vapourization and evaporation to the atmosphere either from the exposed surface of the container or from a liquid pool are included in the model.

A chemical information data base with 41 priority chemicals is coupled to the model. The special advantage of this package is that all programs are capable of utilizing the minicomputer's resident real time observed weather data base of the most recent 24 hours duration from all weather stations in the U.S.A. and Canada.

The package provides numerical results, hazardous zone and chemical information in a very short time, so that their use is highly effective to decision makers. The package is in operation at all times at AES weather centres and it has been used in quite a few emergencies and exercises.

2. MODEL FEATURES

Five different accident types are modelled. Two are for gaseous containers and three are for liquid containers. These are :

in case of only Gas Contents
1) Instantaneous Gas release.
2) Continuous Gas release.

in case of Liquid contents
with rupture above liquid level
3).Continuous gas release due to flashing and/or evaporation.

with rupture below liquid level
4). Instantaneous Liquid release.
5). Continuous Liquid release.

Here "Instantaneous" gas or liquid release is understood when the container is extensively damaged and contents are expected to enter the environment instantaneously. The "Continuous" gas or liquid release is chosen when the rupture size is of definable magnitude and the contents are expected to enter the environment over a period of time.

Excluding fire balls, flame jets and violent cases of Boiling Liquid Expanding Vapour Explosion (BLEVE), all commonly occurring accidents that produce toxic, flammable, and explosive vapour/gas clouds out of released material can be modelled with the above five scenarios.

Discharge rate equations for liquids and gases from containers follow basic principles of thermodynamics and fluid mechanics. Gases are assumed to behave ideally. Equilibrium thermodynamics and isothermal venting processes, although not strictly applicable for sudden punctures and fast releases, are employed for simplicity and to provide quick and reasonably good (conservative) estimates.

2.1 Gas and vapour releases:

Discharge rate from vessels containing only gas or vapours (when the hole is in the tank above the liquid level) under pressure are normally calculated using standard equations for gas flow. These are generally found in Perry's Chemical Engineers' Handbook Perry and Green (1984). Very detailed processes and relevant equations are given by Belore and Buist (1986). Depending up on the ratio of tank pressure to the ambient pressure it is established whether the flow at initial release conditions is critical (sonic) or subcritical (subsonic) and equations relevant to these are used. The discharge rate for a pressurized gas release depends on the coefficient of discharge, area of rupture and other physical properties of the gas. The discharge coefficient with the velocity of approach factor depend on the geometry of puncture and Reynolds number. Following Belore and Buist the discharge coefficient is assumed to be 0.61, Though the rate of release fall during the period of discharge, it is felt adequate to consider initial discharge rate for simplicity. Hence peak discharge flow rates are calculated for both sonic and subsonic conditions. Mass flow rate, duration of release and density of gas up on release are the output parameters for real time weather (ambient) conditions of pressure, temperature and area of rupture (or equivalent rupture diameter).

2.2 Liquid release:

For the case of a liquid whose vapour pressure at the tank temperature is less than atmospheric pressure of 101.3 kPa, (i.e., its boiling point is above the tank liquid temperature)the flow is incompressible and calculated following Bernoulli equation. The liquid discharge rate for a hole below the liquid level in the container is given by standard hydrostatic head, and pressure differential terms and it is also proportional to discharge coefficient and area of rupture. Here the discharge coefficient for various rupture shapes and edge conditions varies from 0.6 to 0.8. An average value of 0.7 is assumed. Also liquid flow by air ingestion is simulated by assuming the tank pressure to be equal to ambient pressure +1 kPa. Thus for such a continuous liquid release situation, the liquid leak rate and the total duration of release are calculated. The liquid that is collected on the surface evaporates and its rate to the atmosphere is calculated by using an evaporation model. With an extensive damage to the container an instantaneous liquid release process is invoked. Amount of gas in the vapour space of the container and its density up on release are calculated and used for puff dispersion model. The liquid that is exposed to the atmosphere evaporates and its rate is calculated. Depending up on the duration of evaporation for the total liquid either a plume or a puff dispersion model is advised for subsequent hazard zone calculations. For a rupture above liquid level only evaporation from the exposed rupture surface is considered.

2.3 Flashing Process:

For the case of liquid that is held in the container as a pressurized liquid (liquefied gases) at temperatures above its normal boiling point, due to rupture to the container, the drop in tank pressure cause part of the liquid to "flash off" or vapourise spontaneously. This continues till the remaining liquid cools to the boiling point temperature. Highly volatile liquids exhibit this phenomenon. Either hole in the above or below the liquid level cause rapid depressurization and very complex processes set in. Usually a mixture of vapour and liquid (two phase flow) set in. We adopted a technique following Briscoe and Shaw(1980) for calculating the fraction of liquid that is flash vapourised. This is simply obtained by balancing the latent heat required to vapourise the fraction to the sensible heat initially stored in the liquid.

$$F = \frac{Cpl * (Tl - Tb)}{Lv + Cpl * (Tl - Tb)}$$

Tl is tank liquid temperature, Tb is boiling point temperature of the liquid, Cpl is liquid sp. heat at constant presssure, and F is the fraction of liquid that is flashed.

For the case of Instantaneous liquid release (extensive damage to the container) the sum of mass of vapour in the vapour space of the container and flashed vapours (mass of liquid * F) constitute as source strength to the puff dispersion in the atmosphere. The remaining liquid which has cooled to its boiling point temperature will evaporate slowly. We assumed that the vapour cloud that evolved out of evaporation and as well as from flashing has initial temperature as that of boiling point temperature of liquid. Hence density of vapour up on release is calculated at ambient pressure and boiling point temperature of liquid. In comparison with air density at ambient conditions either a heavy gas or neutral gas dispersion model is used.

For the case of rupture above the liquid level the vapours in the vapour space and flashed vapours are released either at sonic or subsonic discharge conditions. Strictly speaking here we should have used two phase flow discharge equations, however at present we considered no aersolization and simply used gas discharge equations. The remaining liquid which cooled to its boiling point temperature is considered for evaporation from the exposed surface. The duration of leak for vapours, evaporation, and density of vapours on release determine the nature of dispersion model to be used for hazard area determination.

For the case of hole below the liquid level continuous discharge rate of liquid is calculated using single phase liquid discharge equation. However flash vapourization rate is simultaneously calculated by using F and discharge rate for liquid. As the remaining liquid collects on the surface the pool evaporation process comes into play. Adhering to the conservation of mass the amount of vapours in the vapour space are accounted and for simplicity allowed to flow out over the duration of the liquid leak simultaneously, though it is not correct from the sequence of events and from the two phase flow point of view. For practical purposes if the duration of liquid discharge is less than 3 minutes, the accompanying flashed vapours and vapors in vapour space in total form the source strength for puff dispersion model. If it is longer than 3 minutes the mass flow rates are used as source strength for plume dispersion model, and at the same time evaporation from accumulating pool will be an additional contributor to the source strength. Generally evaporation may continue further in time.

3. Evaporation Process:

Evaporation rate for chemicals that form a liquid pool when spilled on a ground or water surface or exposed to the atmosphere through a ruptured surface area of the container is estimated following Stiver and Mackay (1982):

$$Q = K\ A\ P\ M/\ R\ T$$

Q is evaporation rate (g/s)
A is exposed area of the liquid (m2)
M and R are molecular weight (g/mol) and universal gas constant
P is vapour pressure of liquid at its temperature.(Pa)
T is liquid surface temperature (K)
K the mass transfer coefficient from Mackay and Matsugu (1973) is: $K = 0.0048\ U^{0.78}\ d^{-0.11}\ Sc^{-0.67}$

$Sc=2.7$ for hydrocarbons at environmental conditions
d is equivalent diameter of the pool or exposed surface of the container.(m)
U is wind speed (m/s)

The surface temperature of the liquid is the difficult parameter to estimate. It is a function of many processes, net solar radiation, heat transfer between pool surface and the ground or container, between liquid and the air, and a function of evaporative cooling of the liquid itself. In our model we used for non-flashing liquids T is equal to the temperature of the liquid in while it is containment stage, generally it is the ambient temperature. For flashing liquids T is nothing but boiling point temperature of the liquid. Kawamura and Mackay (1985) compared a few evaporation models with some experimental studies for relatively volatile liquids. Fingas (1987) summarized them. Our results are very encouraging in comparison with their best suggested models (Direct Evaporation model and surface temperature model). Choosing boiling point temperature as liquid pool surface temperature seems to compensate the effects of evaporative cooling and other heat transfers from the environment either day time or night time conditions since these pools are generally much colder than environment. However it is possible for non-volatile liquids for very sunny conditions the chosen ambient temperature could underestimate evaporation rates.

4. Conclusions:

Belore and Buist (1986) have given detailed sequences of events and physical processes and associated mathematical expressions for discharge rates foe gas leaks and for flashable and non flashable liquid releases. They have considered variability of tank pressure, tank temperature and liquid volume and presence of vapour bubbles and sequence of vapour flow to intermittent boiling liquid overflow and other realistic though complex features. This involved an iterative solving of expression at very minute stages (for every 5 cm liquid level changes etc.,). This creates highly time variant source strengths of different kinds with in the short period of the leak span. The dispersion models need an average rate of source strength or the quantity of material released in total with in very short time. In practice, perhaps it suffices to include the effects of various physical processes rather than model them in detail. The present source strength model seems to give reasonable results even in the case of flashable liquid discharges for a hole in the top of tank. In comparison with Enviro Tips manuals, this model gives better results for discharges and evaporation rates. The purpose of EnviroTips is to have ready made nomograms hence they considered constant wind speed and constant ambient temperature and pressure conditions and it did not include flashing process. However our efforts and our modelling package (AQPAC) heavily benefited with the voluminous information and data sets developed for various chemicals. Our package uses real time weather data and chemical data base for real time response of hazardous chemical spills. Finally, it is important to note that model output depends on input parameters. The better the accident type description and scenario input data , the more accurate and realistic will be model results.

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DEMONSTRATION OF MEMBRANE TECHNOLOGY IN ATLANTIC CANADA

by

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ABSTRACT

Three sites in Atlantic Canada were visited during October and November of 1989 by EETD. Microfiltration (MF) and reverse osmosis (RO) were demonstrated at each site and nanofiltration (NF) was tested at two of the sites. The New Brunswick Department of the Environment requested a demonstration of EETD's enhanced oxidation unit for the water contaminated with diesel and gasoline. The results indicated membrane technology successfully separated chemical constituents of concern at each of the three sites during the demonstration. Rejections of 95% were consistently achieved. The rejection of PCP at Domtar was excellent at +99.9% showing that membranes can effectively separate problem organics from groundwater at this site. Preliminary results for the UV/Oxidation unit produced +95% destruction of the BTX contained in the fuel contaminated groundwater at Neguac. A successful integration of membrane technology and UV/Oxidation systems was demonstrated at Neguac.

1.0 INTRODUCTION

The Environmental Emergencies Technology Division (EETD) of Environment Canada develops and demonstrates technology used for spill cleanup and site remediation applications.[1,2,3,4] At the request of the Atlantic Region of Environment Canada, EETD demonstrated membrane technology at three sites in the Maritimes. The demonstrations took place during October and November of 1989 at the Stanfield's plant in Truro, N.S., the Domtar site in Newcastle, N.B., and the Department of Transportation yard in Neguac, N.B. The water streams included: process water containing spent dyes and detergents, groundwater contaminated with wood preservative chemicals, groundwater containing spilled diesel fuel and groundwater contaminated by a leaking gasoline tank. Microfiltration (MF) and reverse osmosis (RO) were demonstrated at each site and nanofiltration (NF) was tested at Stanfield's and at Domtar. The Environment Protection Branch of the New Brunswick Department of the Environment also requested a demonstration of EETD's enhanced oxidation unit at the Neguac site.[6] The description of the processes and the results of the demonstrations are presented in the following sections.

2.0 TREATMENT PROCESSES

2.1 Microfiltration

The MF unit was a crossflow microfiltration system operating in a shell and tube configuration. The feed entered the system on the tube side. The pressure difference (40 psi) forced the filtrate through the membrane to the shell side; the tube side effluent was the concentrated stream, referred to as retentate. Each of the two membrane banks contained one ENKA MD 080 TP 2L polypropylene membrane module with 43 tubes of inner diameter 5.5 mm and of length 3 m. Particles of nominal diameter greater than 0.2 um were rejected by the membranes. The MF was used as a pre RO stage to ensure feed quality and minimize fouling of the NF/RO membranes.

The feed flowrate and pressure was controlled by the operator, along with the retentate flow and the amount of retentate recirculation. The filtrate flowrate was a function of the type of feed, flow conditions and the pressure differential across the membrane. The unit was equipped with a periodic backwash cycle which reduced the particle build up on the membrane surface by forcing filtrate through the pores of the membrane. The backwash could be operated manually if necessary.

2.2 Nanofiltration and Reverse Osmosis

Both the NF and RO processes used spiral wound thin film membranes. The feed entered the pressure vessel parallel to the membrane surface and the concentrate exited at the opposite end. The permeate flowed through the membrane to the core of the vessel and exited through the collector tube at the same end as the concentrate.

A DESAL 5 DK4040F membrane was used for nanofiltration. Uncharged molecules with weights of 100-150 were rejected along with multivalent anion and cations. Univalent ions and lower molecular weight compounds passed through the membrane. Operating pressure could range from 70 to 400 psi with a maximum temperature of 50°C.

A Filmtec SW30HR-4040 RO membrane was used at each site. Low molecular weight compounds such as sodium chloride are rejected by these membranes. Rejections were usually greater than 98% of the initial chemical concentration. The maximum operating pressure for the Filmtec membrane was 1000 psi at a maximum temperature of 45°C.

Both types of filtration operated with the same equipment and pressure vessel, only the membranes were interchanged. The unit was preceded by two 5 um cartridge filters in parallel, to remove any particles which might have fallen into the open air feed tanks. A low pressure pump fed a high pressure pump which delivered the process fluid to the membrane in the pressure vessel. Meters indicated the permeate and concentrate flows, the fluid temperature and the pressure across the membrane. The operator controlled the pressure and the amount of concentrate recirculated.

2.3 Enhanced Photo-oxidation

The Rayox enhanced oxidation process can be used to destroy organic contaminants in water using ultraviolet (UV) photons in conjunction with gaseous or liquid oxidants. The synergistic effect of UV and the oxidant can produce hydroxyl radicals which then promote rapid oxidation of the contaminants. For example, the reaction rates with UV and an oxidant are in the order of 10^6 and 10^9 times greater than with the oxidant alone. The final products of the oxidation reactions are mostly carbon dioxide and water. Other mineralization products are possible depending on the presence of chlorine, nitrogen and metals. Typical oxidants are ozone, hydrogen peroxide and the Enox series of proprietary catalysts.[5] For treatment of the fuel contaminated water at Neguac, hydrogen peroxide and two Enox agents were used. The process was operated in both continuous and batch flow configurations (figure 1) shown schematically below.

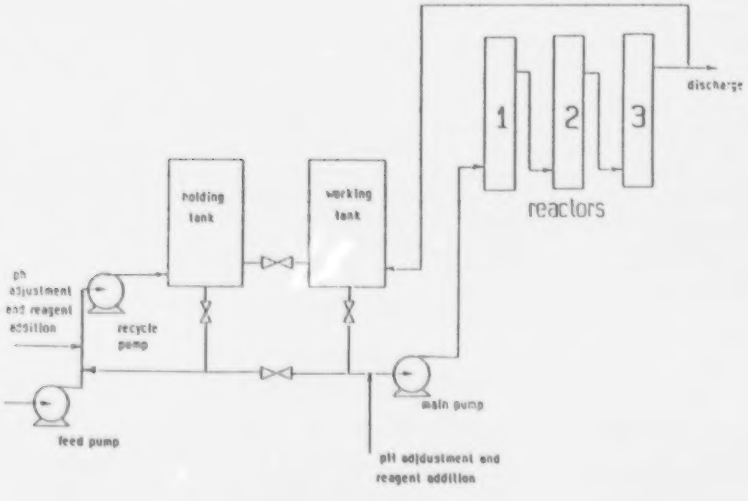
discharge
1
2
3
reactors
holding tank
working tank
ph adjustment and reagent addition
recycle pump
feed pump
main pump
pH adjustment and reagent addition

Figure 1

UV / OXIDATION SYSTEM

3.0 Results and Discussion

3.1 Stanfields

The testing conducted at Stanfields employed all three membrane systems, MF,NF and RO. The MF provided effluent (filtrate) to the NF system thus minimizing foulants from the plants screening system which only removed solids above the 100 mesh level. The plant effluent contained lint and fabric particulate which would have irreversibly fouled any post treatment system using NF and RO, thus the rational for using MF at this site.

The NF was used to process five independent runs. The reason for this was due to the variation in feed concentration and composition. If a certain condition was encountered during processing that damaged the membrane it would be immediately recognized. This could be monitored by taking conductivity readings of the feed and permeate at different intervals to ensure proper functioning of the membrane during each run. The system operated at a pressure of 250 psi and recoveries were maintained at 80 or 90 percent for each of the runs.

The NF flow results (figure 2) show typical membrane performance when using batch concentration. In each case curves were produced indicating a drop in permeate flow over the run time. The separation of the dyes in the effluent was successful (visual interpretation) in all the runs. Salts that had not been rejected by the NF which were retained in the permeate were treated by the RO. Rejection results for calcium (85%) demonstrated the NF system capability to remove the majority of the ionic foulants that are critical in ensuring high permeation flows from the RO. RO rejection results (table 1) indicate that all the tested chemical species had rejections in the +96% range with the exception of copper 74%. Copper was analyzed for comparison purposes only providing additional data when examining results from the Domtar site.

Table 1

STANFIELDS
RO DATA SUMMARY

Test Species	Units	Feed (ppm)	% Rejection
Alkalinity	ppm	37	96.3
TDS	ppm	1640	98.2
Sodium	ppm	510	99.5
Calcium	ppm	8	99.9
Copper	ppb	36	73.9
Chloride	ppm	604	99.7

The RO results (figure 3) showed excellent flow characteristics. Permeation rates never dropped below 4 L/min. The majority of the runs produced flowrates in the 6-7 L/min range. Each of the RO runs was performed with a pressure of 800 psi with recoveries of 80% using a batch concentration mode.

The primary function of the NF in this test was to remove and concentrate the dyes and divalent anions and cations in the process water. The NF pretreatment had produced the desired results in providing quality feed to the RO thus ensuring high productivity.

3.2 Domtar

Testing at Domtar produced good results for flow and chemical rejection by the RO membrane. The use of MF as a pretreatment was employed at this site to provide quality feed for the RO. The use of NF as a pretreatment stage was also tested for comparison purposes. Run 4 (figure 4) was performed using NF. A cleaning of the NF membrane was performed using HCl at a pH of 3 to remove any foulants from the testing at Stanfields. The permeation rate for the NF during run 4 averaged 6 L/min during the two hours of processing. Figure 5 represents the RO permeation flows produced during the demonstration using the two pretreatment systems of MF and NF. The extra quality of the NF permeate provided improved productivity from the RO producing an average increase of 1 L/min for run 4.

The chemical analysis results (table 2) demonstrated that the RO membrane had successfully treated the effluent for the tested constituents. Due to the nature of the site the specific chemicals of interest were the PCP, arsenic and copper concentrations. The success of the trial was measured in the ability of the RO to effectively separate these species from the ground water at the site. The rejection of PCP was excellent averaging +99.9%. Rejection of the copper and arsenic (88% and 96%) species was good considering feed concentrations were in the low ppm range. The RO membrane produced water containing low ppb concentrations of all the tested species. The concentrate stream was put back into on site storage tanks and was not treated due to time and equipment limitations.

Table 2

DOMTAR
RO DATA SUMMARY

Test Species	Units	Feed (ppm)	% Rejection
Alkalinity	ppm	2	99.9
TDS	ppm	4485	99.8
Arsenic	ppm	1	95.8
Copper	ppm	2	87.7
Phenol	ppb	43	74.1
Cresols	ppb	34	92.2
PCP	ppb	10363	99.9
Oil & Grease	ppm	27	93.6

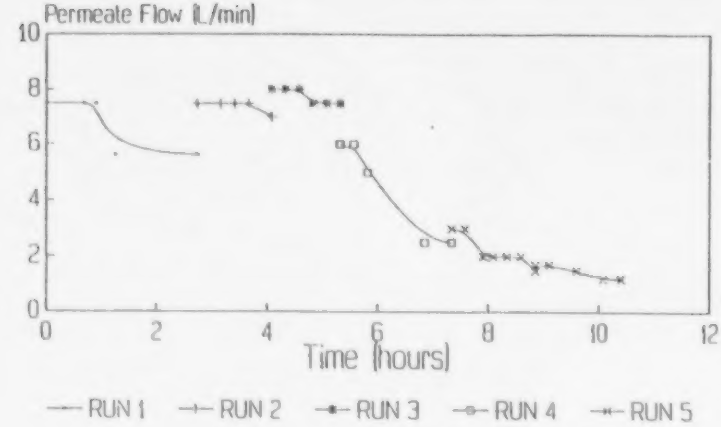

Figure 2

STANFIELDS, Truro, N.S.
COMBINED NF RUNS

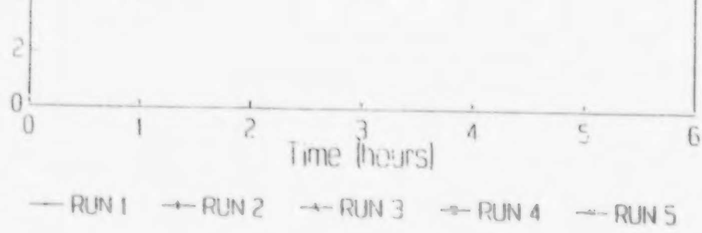

Figure 3

STANDFIELDS, Truro, N.S.
COMBINED RO RUNS

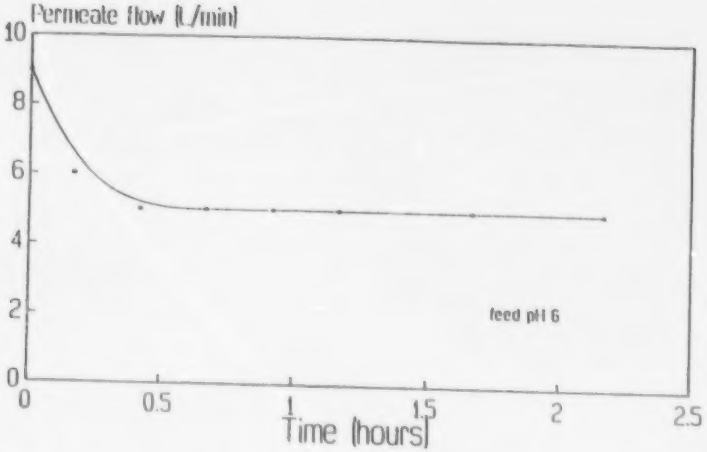

Figure 4

DOMTAR, Newcastle, N.B.
NF RUN 4

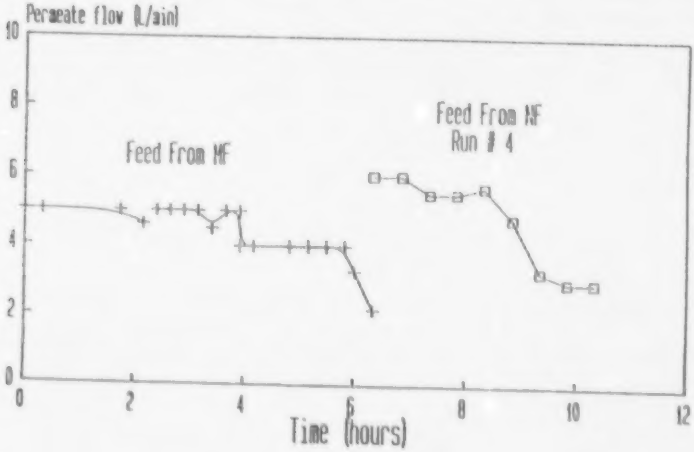

Figure 5

DOMTAR, Newcastle, N.B.
COMBINED RO RUNS

The feed fluid was treated by NF under the following conditions. Batch concentration mode with recoveries of 80% under an applied pressure of 400 psi. The NF permeate produced was retained as feed for the RO which also used batch concentration under an applied pressure of 800 psi with recoveries of 80 %. The above conditions explain the flow curves produced during the RO testing in figure 5 as the feed concentration increased over time.

3.3 Neguac

The integration of membrane technology and UV/Oxidation treatment was demonstrated on the fuel contaminated groundwater at the Neguac transportation yard. The results of the testing has not been finalized for the UV/Oxidation system and therefore only preliminary results are presented.

The process train followed the diagram (figure 7) where MF filtrate fed the RO and the two membrane effluents, the MF retentate and RO concentrate were collected and used as feed for the UV/Oxidation system. The two discharge streams, the RO permeate and UV/Oxidation product water were returned to a second well up stream of the feed well.

Flow results for the RO showed very stable levels between 8 and 10 L/min (figure 6) with no appreciable drop encountered during the 25 hours of processing. Two RO membranes were used in series under the following conditions. Pressures of 800 psi and recoveries of 80% were maintained throughout the trial. The lack of curvature in the permeate flow was due to the low concentration of chemical constituents present in the feed (table 3). The rejections for the inorganic species all surpassed the 96% level. The rejections for the volatile organics all surpassed the 90% level. The BTX rejections are consistent with theory in that the more polar and higher molecular weight compounds exhibit better rejections, 90% for benzene and +98% for the xylenes.

Table 3

NEGUAC
RO DATA SUMMARY

Test Species	Units	Feed (ppm)	% Rejection
Alkalinity	ppm	9	97.0
TDS	ppm	421	96.8
Magnesium	ppm	5	99.7
Calcium	ppm	32	99.8
Benzene	ppb	808	89.9
Toluene	ppb	137	92.2
p-Xylene	ppb	28	98.2
o/m-Xylene	ppb	29	98.1

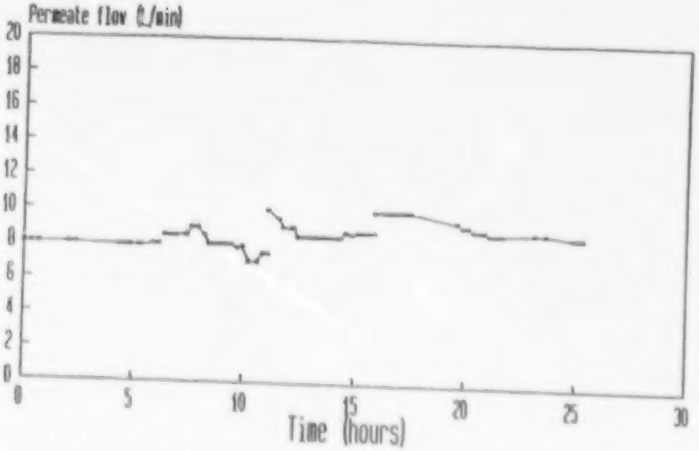

Figure 6

**D.O.T., Neguac, N.B.
COMBINED RO RUNS**

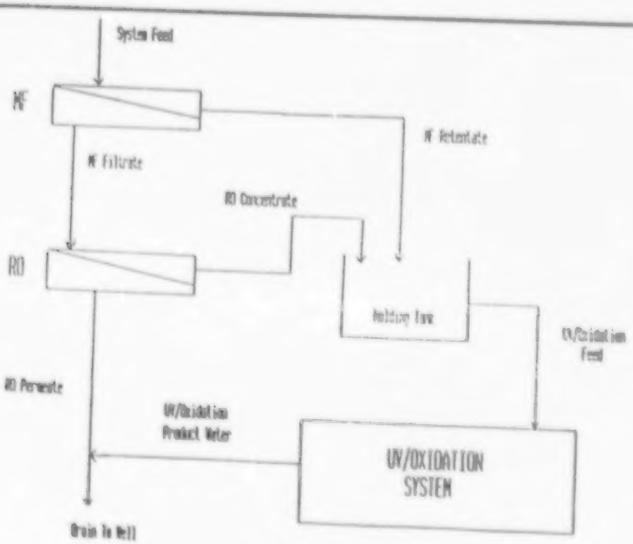
System Feed
MF
MF Filtrate
MF Retentate
RO Concentrate
RO
Holding Tank
UV/Oxidation Feed
RO Permeate
UV/Oxidation Product Water
UV/OXIDATION SYSTEM
Drain To Well

Figure 7

PROCESS TRAIN AT NEGUAC

Preliminary results from the UV/Oxidation system indicated excellent destruction percentages for the volatile organics tested at this site. The data below demonstrates the potential of this treatment system to effectively process organic contaminants.

VOC Constituents (ppm)

Time (min)	Benzene	%Destroy	Toluene	%Destroy	Xylene	%Destroy
0	36	0	54	0	28	0
15	2.4	93.3	1.4	97.4	.57	98.0
30	.63	98.3	.03	99.9	N/D	+99.9

Operating conditions:

a) 18 kw of UV.
b) Presence of H_2O_2
c) 260 L Batch Run
d) Feed was previously drummed groundwater.

4.0 Conclusions

Membrane technology successfully treated the dye waste at Stanfields. The use of NF successfully removed all coloration. The RO produced quality permeate suitable for use as plant water such as boiler feed for steam generation.

The MF/NF comparison to provide quality feed for the RO was demonstrated at Domtar producing results that favour the use of NF over MF for this specific groundwater.

The rejection of PCP (99.9%) at Domtar demonstrated that membrane technology can provide excellent separation of this compound from groundwater at this site.

Waste stream problems encountered in previous RO tests were eliminated by using additional treatment technology to process RO concentrate. This was demonstrated successfully at Neguac with the integration of Membrane Technology with UV/Oxidation in the treatment of fuel contaminated groundwater.

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BUTANE STRIPPING AS AN EFFLUENT TREATMENT TECHNIQUE

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ABSTRACT

Paper describes a new technique using liquid/liquid extraction to preferentially absorb organic contaminants, from spills, contaminated waters or plant effluents, into liquid butane. The process involves contacting butane and the aqueous stream to be treated in a counterflow contactor, such that the liquid phase is maintained.

Separation of the butane and aqueous layers, and their separate further treatment is described. Butane is purified so that it can be recycled to the process. Water is "debutanized" to recover dissolved butane and to permit its discharge to the environment.

Results from bench-scale and continuous counterflow pilot-plant work are presented, with correlations for predicting the performance of a Butane Stripper. Design features of a proposed commercial unit (for a Houston, TX petrochemical plant) are described.

INTRODUCTION

In 1986, Supply & Services Canada, on behalf of Environment Canada, issued an invitation to consultants to supply their qualifications to develop a steam stripper as an environmental emergencies counter-measure. Thinking that there may be a better way to treat the problem, Mr. W. B. Alderton, P.Eng., the President of Pan Canadian Consultants Limited, of Vancouver, B.C., devised an alternative theoretical process, which was called "Butane Stripping", to differentiate it from steam stripping.

Pan Canadian Consultants Limited submitted an Unsolicited Proposal to the Federal Government to examine the concept of the Butane Stripping process. The proposal was accepted for financial support under the Unsolicited Proposal Program of Supply & Services, with sponsorship by the Environmental Emergencies Technology Division of Environment Canada.

The process has passed through two stages of development: Stage I - tests in a small bench-scale unit; and Stage II - tests in a continuous flow pilot-plant. The Stage I and II work was completed in the laboratories of the Department of Chemical Engineering, University of British Columbia. The technology is now ready for its next stage of development - commercialization.

All rights to, and knowhow in, Butane Stripping previously belonging to Pan Canadian Consultants Limited and/or Mr. Alderton have been assigned to Sierra Environmental Services Inc., a company formed by Mr. Alderton and others to commercialize the technology. It is Sierra's intention to have the first commercial-scale plant in operation by the end of 1990.

DESCRIPTION OF THE PROCESS

In Butane Stripping, water contaminated with organic compounds is contacted with liquid butane in a pressurized contactor. The organics are preferentially absorbed in the butane which can be separated easily from the aqueous layer, thus effecting a purification of the contaminated water. A block flow diagram for the process is shown in Figure 1.

The individual process steps are as follows:

1. Contactor

The contaminated water and butane are mixed in a single or multi-stage contactor to effect the transfer of organic from the aqueous phase to the butane phase. Ambient temperature is used and the pressure is sufficient to maintain the liquid phase. The number of mixing stages and residence time are determined by the characteristics of the water and the contaminant removal required.

2. Separator

The water and butane are allowed to settle and to separate. The separator may be a separate unit or may be integral with the contactor. The required separation time is determined from bench-scale tests. In general, for waters containing no detergents, the time for complete separation is very short (< 60 seconds).

3. Fractionator

The butane layer is fed from the separator to a fractionation column. This is a packed column designed to provide the required butane purity for recycle to the process, and its design is dependent upon the characteristics of the water to be treated and on the effluent guidelines.

The objective of the fractionator is to produce pure butane vapour from the top (99.999%+) and a concentrated pollutant stream as a bottom product. The butane vapour from the top of the fractionator is compressed, cooled, reliquefied and returned to the process.

The fractionator bottom product will contain up to 10% of the pollutant organics. It may be further fractionated to produce a concentrate up to 80% of the pollutant for recovery or incineration.

4. Debutanizer

Water leaving the separator is saturated with dissolved butane under contactor conditions. This butane must be removed to satisfy effluent guidelines, and also to economize on butane consumption. The debutanizer is a packed column operating under reduced pressure, with butane vapour being collected by a vacuum pump. The vapour is fed to the suction of the main butane compressor for recovery.

5. Aerator

Water leaves the debutanizer containing 5 - 10 ppm of dissolved butane. While this is not a significant economic loss to the process, it is excessive for discharge to the environment. Consequently, the water stream is aerated to reduce the dissolved butane concentration to an acceptable level. The aerator is an air-blown packed column which is designed to reduce the residual butane to the range 0.2 - 0.5 ppm. Following aeration, the water is discharged to the receiving stream.

DISCUSSION OF RESULTS

Work to date has been accomplished in two Stages. In Stage I, a small, single-stage, bench top apparatus (capacity about 0.75 l) was developed and utilized. In Stage II we designed, constructed and utilized a continuous, counterflow pilot-plant with 4 actual mixing stages (about 1.4 theoretical stages) and flows of 80-100 ml/minute water:15-25 ml/minute butane.

During the Stage I work (bench-scale) and Stage II work (pilot-plant) a total of 25 different organic pollutants were tested, either singly or in combination in water. It was found that not all organic compounds can be removed from water via Butane Stripping. The process is very effective on non-polar organics, and somewhat ineffective on very polar organics. This shows up in Table 1, where the poorest extraction is obtained on the most water-soluble organics.

Table 1

Results from synthetic waste waters

Chemical	Initial concentration	Removal efficiency (%) Actual [1]	Predicted[2]
Benzene	166-960 ppm	97.5-99.7	99.9+
Bromobenzene	90 ppm	99.8	99.9+
n-Butyl acetate	974 ppm	96.3	99.5
C tetrachloride	385 ppm	98.2	99.5+
Chlorobenzene	124 ppm	99.5	99.9+
Chloroform	4,475 ppm	96.5	99.5+
m-cresol	1.03 %	17.5	25
o-cresol	1.10 %	20	30+
Cumene	25 ppm	99.98	99.99
Dichlorobenzene	30-74 ppm	99.8-99.9	99.9+
Ethyl acetate	2.05 %	58	75+
2-Ethyl hexanol	503 ppm	94.3	99+
Ethyl benzene	57 ppm	99.8	99.95+
Ethylene dichl.	400-4540 ppm	98-99.9	99.95+
Ethylene dibrom.	1,697 ppm	97.2	99.5+
MEK	3.51 %	20.4	30+
Methanol	10.1 %	22.6	30+
Methylene chl.	6,857 ppm	88.2	95+
Perchloroethylene	25-93 ppm	95.6-99.8	99.9+
Phenol	4 %	12.8	20
Phenol	1,700 ppm	96.5	98+ [3]
Styrene monomer	124 ppm	99.8	99.95+
Tet.chloroethane	88-397 ppm	98.0-99.9	99.9+
Trichloroethane	640 ppm	98.9	99.9
Toluene	219 ppm	99.7	99.9+

Notes to Table 1:

[1] Removal efficiency actually measured in laboratory bench-scale or pilot-plant tests

[2] Predicted removal efficiency based on the expected performance of a commercial butane stripping unit, compared with the measured performance of the pilot-plant.

[3] Phenol removal using butane stripping with a co-solvent in the pilot-plant. Further work planned to optimize the co-solvent extraction for polar organics (eg. phenol; methanol; MEK; acetone).

The laboratory test results allowed us to develop a correlation for organic homologues. The empirical model relates the distribution coefficient (K_D) of any organic compound between water and butane with its solubility (S) in water @ 20°C. The proposed relationship is:

$$\log_{10} K_D = a + b. \log_{10} S$$

Examples of specific correlation factors for different homologues are:

Hydroxyl compounds	a = 0.216	b = -0.649
Halogenated aliphatic HCs	a = 1.588	b = -0.944
Aromatic HCs	a = 1.480	b = -0.954
Halogenated aromatic HCs	a = 1.405	b = -0.902
Carbonyl compounds	a = 1.613	b = -1.032

Examples of specific extractions are shown in Figures 2 - 5. Figures 2 - 4 show the typical rapid equilibrium reached for many common non-polar priority pollutants (1,1,1-trichloroethane; dichlorobenzene; perchloro-ethylene). Figure 5 shows the slower equilibrium and poorer extraction with a typical polar organic pollutant (methanol).

The laboratory results provided two important conclusions. First, the results from the single-stage benchtop apparatus correlate exactly with the results from the multi-stage pilot-plant. Second, the results confirm the theoretical postulation that extraction efficiency is independent of initial concentration.

Subsequent to the above test results, additional tests were done on "real world" sample waters, containing multiple organic compounds. Two examples are presented here: a contaminated groundwater from Neguac, New Brunswick; and a plant effluent from Houston, Texas.

Neguac sample.

Water from Neguac was collected from beneath a Department of Transport garage. It had been contaminated with spilled fuel and contained benzene, toluene and xylenes. It is probably typical of waters in the vicinity of leaking gasoline storage tanks.

The sample was given a single stage extraction in a batch test apparatus, using pure butane as the extractant. Results are presented in Table 2.

Table 2
Results from actual groundwater
(Neguac, New Brunswick, Canada)

Chemical	Initial concentration	Removal efficiency (%) Actual [1]
Benzene	48.0 ppb	95
Toluene	31.2 ppb	99
Xylenes	6.5 ppb	99

Note to Table 2:

[1]. Actual efficiency as measured by GC-FID.

Gas chromatograph traces (Figure 6) are appended for the untreated "soup" and the water after it had received a single-stage extraction in the bench scale apparatus.

Clearly, Butane Stripping is a very effective technique for removing BTX from water. A multistage process should give over 99.5% removal of all BTX, with the only limitation being the butane purity available from the fractionator. To produce water containing 1 ppb of BTX, it is necessary to have butane purity of 99.9999%. This has not yet been demonstrated, although we have a design for a column to produce 99.999%, and we have achieved 99.995% from our pilot-plant.

Houston chemical plant sample

A sample was received from a petrochemical plant in Houston, Texas. The sample was of plant effluent being discharged from a physical-chemical treatment plant, but which was non-compliant for several organic compounds.

The major problem with the effluent stream, both for the chemical plant and for our test program, is its extremely high TOC and COD content. The plant produces about 30,000 USG/d (113,500 l/d) of waste water containing 30-35,000 mg/l COD. Most of the COD loading is of relatively innocuous organics (eg. ethylene glycol), but there are also priority pollutants (eg. ethyl benzene, toluene) that must be removed and/or reduced. The high COD means that conventional carbon systems (GAC or PACT) are uneconomic.

The effluent is so loaded with organics that determination of individual contaminant concentrations using our GC-FID is impossible. [Undoubtedly GC-MS analysis would be more appropriate to provide the data required, but was not done in this study because of the cost]. We therefore took the sample and spiked it with known quantities of the priority pollutants of concern, so that we knew the original concentrations in the effluent. After the extraction, we sampled the butane layer and analysed for the priority pollutants. This procedure gave a "clean" sample, from which we could determine the extraction efficiency as shown in Table 3.

Table 3
Results from an actual plant effluent
(chemical plant, Houston TX)

Chemical	Initial concentration[1]	Removal efficiency (%) actual[2]	Removal efficiency (%) predicted[3]
Benzene	26.5 ppm	78+	98
Ethyl benzene	26.5 ppm	77	96
Trichloroethane	26.5 ppm	70+	88
Toluene	26.5 ppm	74	93
Napthalene	3.1 ppm	70+	88
Phenanthrene	0.7 ppm	70+	88

Notes:

[1] Initial waste water received from Houston contained such a mixture of organics that it needed spiking with known quantities of the tabulated organics to allow calculation of extraction efficiency. Initial concentration is after spiking with a stock solution.

[2] Calculated from organic concentrations measured in the butane layer after the extraction, using GC-FID.

[3] Sampling and analysis of the butane layer (rather than the water layer, as is usual) leads to losses of butane and contaminant organics, and to underestimation of extraction efficiency by about 20%. The predicted efficiency is obtained by adding a correction of 20% to the actual result shown in column 2.

Some measure of the difficulty involved in the analysis can be seen by referring to Figure 7. This is a GC-FID trace for the effluent sample we received from Houston.

As a result of the single-stage extraction, we were able to make a proposal for a Butane Stripping system for the Houston plant. A schematic of the system, with vessel sizes and capacities, is shown in Figure 8. The proposed system will treat 20 USG/minute (75 l/minute) of water, and will produce a concentrate for incineration (or recovery) of about 5 USG/day (20 l/day). Direct operating costs are projected to be about $0.004/USG (≈$0.001/litre).

Currently, the chemical company personnel are attempting to avoid any expenditure on additional waste treatment plant by eliminating the pollutants of concern from their plant effluent, i.e. by using in-plant controls. If they cannot eliminate them, they have advised their consultants and the City of Houston that they will select a Butane Stripping system, based on its very favourable economics over carbon-based systems.

FUTURE DEVELOPMENTS

Sierra Environmental Services Inc. is determined that Butane Stripping will be marketed as a technology for the clean-up of contaminated waters, plant effluents and spills. Units can be constructed for fixed locations (eg. plant effluent treatment) and for portable uses (eg. spill clean-up). Unit capacities are visualized from about 5 USG/minute (20 l/minute) to about 50 USG/minute (200 l/minute).

Its efficiency at low concentrations and at high concentrations is equally good, and this offers opportunities for widespread applications for the technology. Sierra is currently pursuing market opportunities in several States as well as in Canada. We anticipate an order for the first commercial unit during 1990, with start-up before the end of the year.

We have applied, jointly with a U.S. university, for assistance from the National Science Foundation in development of a Butane Stripping system for soils and sludges. We are hopeful that financial assistance will be made available later this year. We believe that contaminated soils can be treated successfully to remove chemicals such as PCBs, pesticides, etc.

We have commenced discussions with a U.S. corporation to explore combining a new technology it is developing with Butane Stripping in joint-venture projects. The combined technologies may make it possible to produce potable water from petrochemical plant effluents - even those containing some rather unpleasant organics.

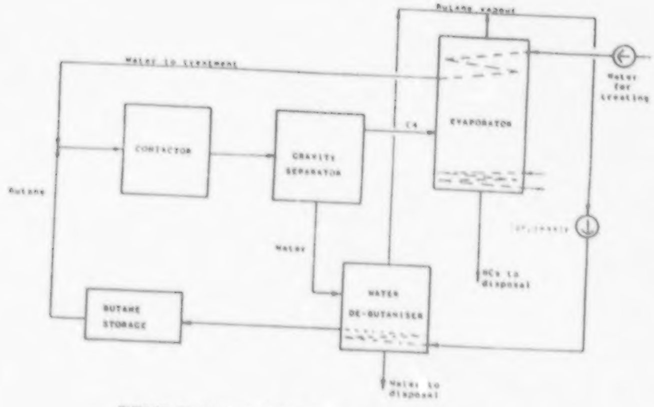
CONCLUSIONS

Butane Stripping has yet to demonstrate commercial feasibility. However, it is apparent from the bench-scale and pilot-plant test work done to date that it is an effective treatment technique for the removal of a very large number of organic chemicals from water, although it is not a panacea.

The extraction performance of a Butane Stripper can be predicted from the solubility of the organics to be extracted, and from their chemical "family". This follows work on correlations of K_D value, and it removes much uncertainty from consideration of the technology as a treatment process.

The technology has been shown to be equally effective in removing high concentrations of organics from water (> 1,000 ppm) and in removing low concentrations (< 1 ppm). This confirms its theoretical extraction performance, i.e. extraction efficiency is independent of initial concentration.

Water quality leaving the process (in terms of dissolved butane content) is acceptable for aquatic organisms, and the total butane loss from the system to the environment is very low.


Butane vapour
Water to treatment
Water for treating
CONTACTOR
GRAVITY SEPARATOR
C4
EVAPORATOR
Butane
Water
HCs to disposal
BUTANE STORAGE
WATER DE-BUTANISER
Water to disposal

BUTANE STRIPPING BLOCK FLOW DIAGRAM Figure 1.

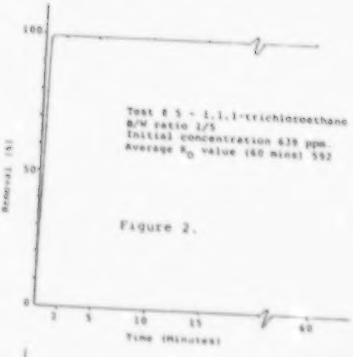


Figure 2.

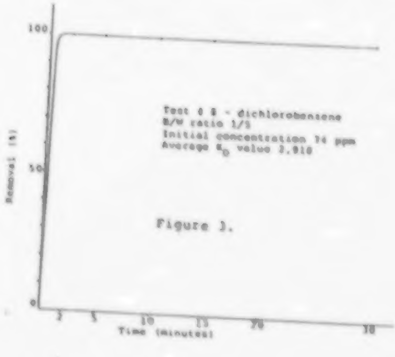


Figure 3.

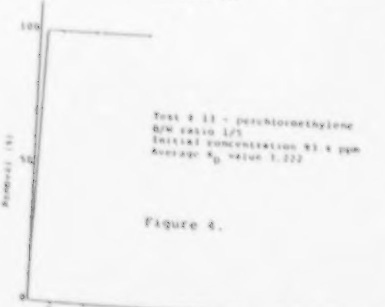


Figure 4.

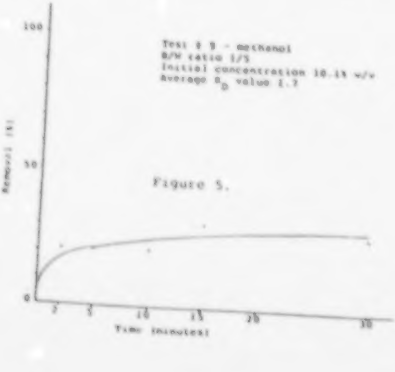
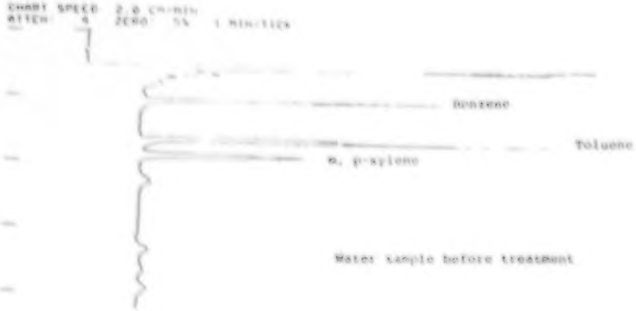
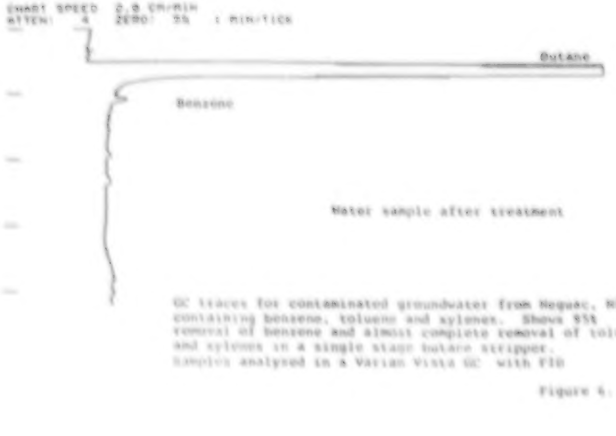


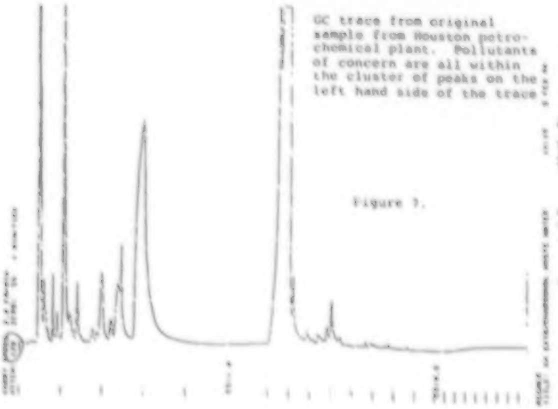
Figure 5.





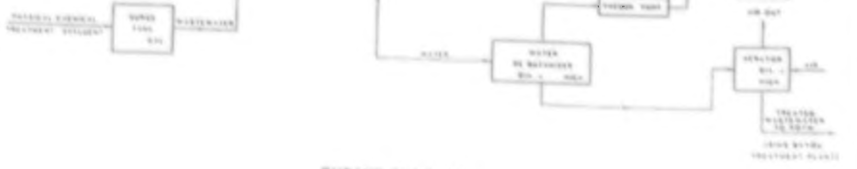
GC traces for contaminated groundwater from Neguac, NB containing benzene, toluene and xylenes. Shows 85% removal of benzene and almost complete removal of toluene and xylenes in a single stage butane stripper. Samples analysed in a Varian Vista GC with FID

Figure 6.



GC trace from original sample from Houston petrochemical plant. Pollutants of concern are all within the cluster of peaks on the left hand side of the trace

Figure 7.



BUTANE STRIPPER
BLOCK FLOW DIAGRAM

(Typical for 20 gpm plant proposed for Houston, TX)

FIGURE 8

THE ILLEGAL DUMPING OF PHOSDRIN IN A MUNICIPAL LANDFILL, JAMAICA: SOME LESSONS LEARNT

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ABSTRACT

On May 18, 1988, the Office of Disaster Preparedness (Jamaica) was alerted by the casualty department of a regional hospital which had treated three persons for acute chemical poisoning.

Investigations revealed that some ninety-odd three-gallon containers of phosdrin concentrate had been dumped at a municipal landfill site and was posing a threat to residents of the area, who had free access to the site. A major underground aquifer, adjacent to the site, was also in danger of being polluted.

This incident highlighted the need for a comprehensive hazardous materials management programme in Jamaica, and showed the vulnerability of an uninformed public to threats of this type.

This paper reviews the response and clean-up operations, and makes recommendations for more effective hazardous materials management. These recommendations can be applied to Jamaica and similar developing countries.

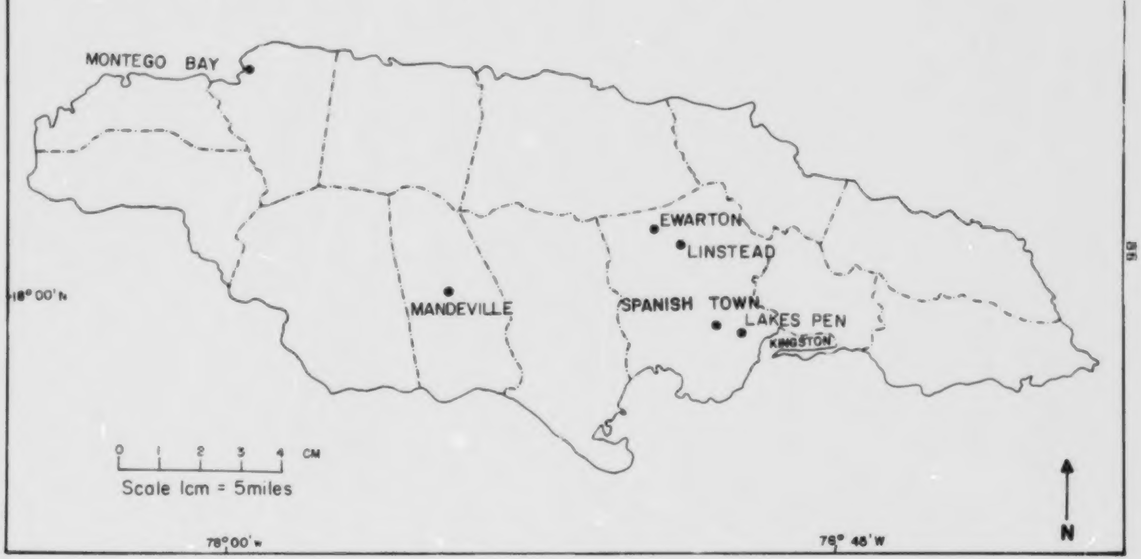
INTRODUCTION

Sequence of Events

On Wednesday May 18, 1988 the Office of Disaster Preparedness (ODP) was alerted by a doctor at a hospital in Spanish Town (Fig. 1) to the dumping of an unspecified quantity of the chemical Phosdrin (Mevinphos) in a municipal landfill site at Lakes Pen (Fig. 1). The hospital became aware of the problem when three persons had to be treated for organo-phosphate poisoning. Two of the three were severely affected and were admitted to the hospital. The third, a nine-year-old boy, was treated and sent home.

MAP OF JAMAICA

FIG I


MONTEGO BAY
EWARTON
LINSTEAD
MANDEVILLE
SPANISH TOWN
LAKES PEN
KINGSTON
18° 00' N
0 1 2 3 4 CM
Scale lcm = 5miles
78° 00' W
76° 48' W
N

The ODP contacted the Underground Water Authority (UWA) and the Natural Resources Conservation Department (NRCD) and a site visit was arranged for that afternoon. The Fire Service was notified but not asked to respond. Of immediate concern was the presence of an alluvial aquifer estimated to be about thirty feet below the surface in that area. A number of wells tapping the aquifer provide water for sections of the Kingston Metropolitan Area and St. Catherine (Fig. 2). It was feared that downward migration of the Phosdrin through the sandy layers at the site might cause contamination of the aquifer. The Rio Cobre river, an important source of surface water, borders the northern margin of the site (Fig. 3). Another cause for concern, therefore, was pollution of the river through base flow from the aquifer if it was contaminated.

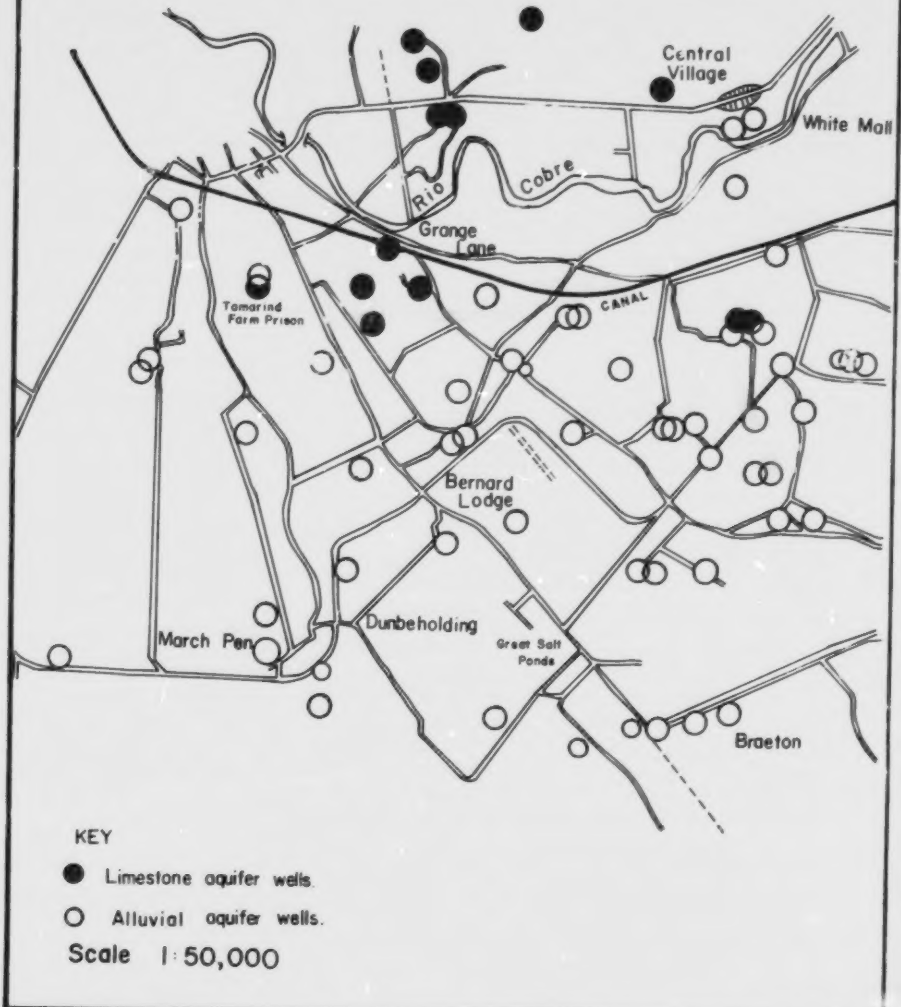
At the site, the Government team spoke with representatives of the polluter company and the caretaker of the landfill site. From these discussions, the following sequence of events was put together.

The person who dumped the chemical was an employee of a large multi-national company. The Phosdrin had been in storage for some time and the containers had begun to deteriorate. The company therefore decided to dispose of the pesticide and obtained permission from the Food Storage and Prevention of Infestation Division of the Ministry of Foreign Affairs Trade and Industry, to dispose of it at a site already used by the company for disposal of industrial waste. Neutralizing with sodium hydroxide solution which speeds breakdown of Phosdrin was stipulated in the letter of permission. The employee assigned responsibility for the safe disposal of the Phosdrin was a certified handler of poisons and had received extensive training in safe handling practices. On Saturday May 14, he was assigned a vehicle and appropriate protective gear and left the company's Kingston premises bound for Mandeville approximately sixty miles away (Fig. 1), with ninety-five containers of Phosdrin.

On Tuesday May 17, the caretaker of the Lakes Pen landfill visited the polluter's Kingston office and reported that on Saturday May 14 a man driving a company vehicle had hired two men to unload containers and then to wash the vehicle. The containers were buried in a trench approximately ten feet deep by the tractor at the site. Shortly

FIG. 2

WELL — LOCATION MAP OF LAKES PEN ST. CATHERINE



Central Village
White Mall
Rio Cobre
Grange Lane
CANAL
Tamarind Farm Prison
Bernard Lodge
Dunbeholding
Great Salt Ponds
March Pen
Braeton
KEY
● Limestone aquifer wells.
○ Alluvial aquifer wells.
Scale 1:50,000

thereafter several of the caretaker's pigs died after bathing in the pool of water left from the washing of the pick-up, and the two men who had unloaded the pick-up became very ill and had to be taken to hospital.

The Lakes Pen Landfill

This municipal dump is situated approximately ten miles west of Kingston (Fig. 1). It has been operated by Local Government for approximately twenty years and is designated as a site for household refuse and certain types of non-hazardous industrial waste. The site, occupying about fifteen acres near the south bank of the Rio Cobre fills a depression left by largely illegal sand mining activities.

IMMEDIATE RESPONSE

On receiving the report the company immediately started investigations into the incident. Once it was ascertained that all the Phosdrin had been dumped at Lakes Pen they took the following steps:

i) Notified the government agency responsible for the landfill, cordoned off the area and placed it under tight security.

ii) Notified the parent company abroad.

iii) Invited Government Regulatory Agencies to a meeting on Thursday, May 18.

iv) Began making preparatory arrangements for clean-up.

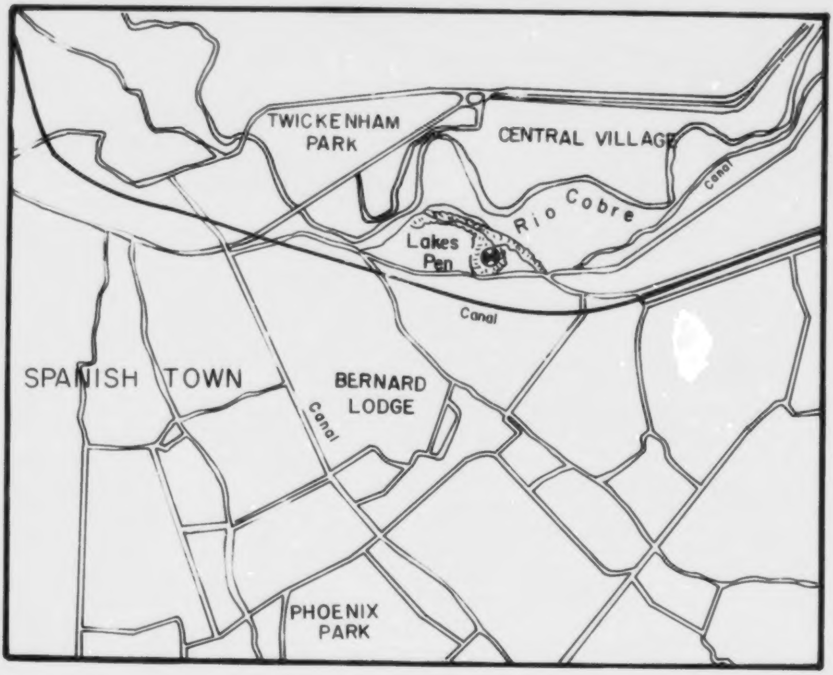
At the meeting on Thursday, May 18 there was general agreement that:

i) The contaminated debris would be treated with sodium hydroxide until a concentration of one ppm or less Phosdrin was attained, after which it would be buried in a sealed area.

ii) The contaminated debris should be excavated and removed to the company's premises for temporary storage while the Phosdrin was neutralized.

FIG. 3

LOCATION MAP OF LAKES PEN ST. CATHERINE


TWICKENHAM PARK
CENTRAL VILLAGE
Rio Cobre
Canal
Lakes Pen
Canal
SPANISH TOWN
BERNARD LODGE
Canal
PHOENIX PARK

KEY

● Phosdrin disposal site.

Scale 1:50,000

iii) Delineation of the area of contamination was to be carried out by a drilling programme to determine whether the Phosdrin had migrated laterally or vertically through the layers of sand, silt and rubbish present.

iv) A programme to monitor surface and underground water was to be set up by the Underground Water Authority.

CLEAN-UP AND TEMPORARY STORAGE

Excavation and removal of the contaminated debris was carried out on Saturday, May 20 to Sunday, May 21 by the polluter under supervision of the Regulatory Agencies. The debris was mixed with calcium oxide, sprayed with sodium hydroxide solution and transported by road to the holding area approximately twenty miles away. There it was placed in ten forty-foot shipping containers acquired for that purpose.

Also excavated were twenty tons of fish which earlier had been disposed of in the same pit as the Phosdrin. Forty-eight hours after its removal and relocation the smell of fish and Phosdrin prompted a delegation of citizens from a near-by community to visit the company's offices in protest. The labour union representing the company's employees then served an ultimatum on the company to have the debris removed or risk industrial action.

The situation was eventually diffused after regular briefing meetings were arranged for citizens and employees. Applications of potassium permanganate and covering with layers of earth reduced the smell to tolerable levels.

DELINEATING AND MONITORING CONTAMINATION

This was a three - phase operation involving:

i) Drilling and sampling in and around the excavated area.

ii) Monitoring of ground and surface water.

iii) Monitoring of contaminated debris.

(i) Drilling and Sampling

Drilling and sampling were initiated after removal of the contaminated soil. Borings were spaced at twenty-two - twenty-five feet on a three by six grid centered on the excavation. Samples were taken at intervals between six inches and twenty feet depth at the nodes of the grid, and split three ways with one split going to the company involved, one to the Government of Jamaica and one to United States laboratory of the polluter's consultant.

(ii) Monitoring Ground and Surface Water

Monitoring of groundwater at the site was achieved by sampling of three wells drilled specifically for that purpose within five-hundred feet of the trench. Drilling of these wells was necessary as there were no groundwater sampling points at Lakes Pen. Surface water sampling of the river was also done. No contamination of ground or surface water was detected.

(iii) Monitoring of Contaminated Debris

Sampling of debris being held in storage was carried out regularly between June and November at which time Phosdrin degradation was complete and permission was given for burial.

FINAL DISPOSAL OF DEBRIS

The Regulatory Agencies and the polluter agreed that final disposal of the contaminated debris should be done in a manner which would ensure no interaction with the environment and which would allow long-term monitoring of the waste. A site was chosen which had naturally occurring clay beds, approximately twenty feet thick. A two - foot layer of compacted clay was placed on top of this, overlain by six inches of free - draining gravel topped by a further two feet of clay. The debris was place within this seal and covered with a further two feet of clay and twelve inches of marly limestone. Top soiling and planting of grass was carried out as a means of erosion control. A slight slope permits run-off and minimizes ponding which might lead to vertical seepage.

Monitoring for breaching of the primary clay layer is done by means of a perforated three inch pipe installed in the free-draining gravel layer. Final disposal took place on December 30, 1988.

PROBLEMS ENCOUNTERED AND LESSONS LEARNT

(i) Lack of Designated Disposal Sites

The most critical problem highlighted by this incident was the absence of designated sites for hazardous waste disposal. Fortunately, in this case, the polluter was identified and had the resources to properly dispose of the waste. Had this not been the case it is likely that the debris would still be in temporary storage.

Any site chosen should be reasonably close to the main sources generating the waste. Transportation over long distances will clearly be a disincentive, and might result in illegal disposal, as happened in this case.

(ii) Need for Better Monitoring of Landfill Sites

Before this incident, access to the dump was virtually uncontrolled. Gaps in the fence permitted unrestricted access to vehicular and pedestrian traffic. In the absence of the caretaker any type of waste could be dumped there and be immediately buried by the tractor permanently working at the site, without the knowledge of Regulatory Agencies. It is recommended that such sites be fenced and the content of incoming trucks be closely monitored. Clear guidelines should be given to site staff on what is prohibited from being dumped.

(iii) Adequate Legislation to Address Incidents of this Type

The dumping of the chemical was in contravention of several Public Health - related laws. However, none of these laws carry stiff penalties for offenders. There is need for comprehensive legislation specifically addressing hazardous materials incidents. This legislation should cover responsibility for clean-up and restoration costs, compensation for damage to humans and the environment, as well as imposing of stiffer penalties for contravention.

(iv) Clarification of Roles of Agencies

Disposal of hazardous materials should not be undertaken without input from the environmental management agencies. Any legislation dealing with hazardous materials management should also address the roles and responsibilities of environmental management agencies, the water authority and the emergency management agencies.

(v) Better Siting for Municipal Dumps

In the past, municipal dumps have been sited without benefit of environmental impact assessments. As a result many are sited in environmentally sensitive areas where serious environmental damage can result if an accident occurs. Better coordination among environmental agencies, the Public Health Departments, the Underground Water Authority and the Local Municipal Councils is needed to ensure proper siting of landfills.

(vi) Need for an Informed Public

Ignorance of the toxic nature of many pesticides and common household chemicals is widespread and leads to improper storage, handling and disposal of chemicals, as well as to many incidents of poisoning. Public awareness programmes have been run for farmers. A more widespread programme aimed at all sectors should now be considered.

(vii) Need for a "Clean-up Fund"

The direct cost of clean-up and disposal of the debris was US$110,000 (J$605,000). Had the polluter not paid, this cost would have fallen to the regulatory agencies. However, it is unlikely that these agencies would have been able to fund the operation from normal budget sources which are usually inadequate even for planned programmes.

It is therefore recommended that a hazardous materials contingency fund be established which could be drawn on for incidents in which the Government has to initiate and implement the clean up of spills.

(viii) The Importance of a Contingency Plan

Although the National Pollution Contingency Plan was not activated for this incident, the procedures employed by the ODP were standard procedures as laid down in the plan. Benefits of having a plan include standard procedures for rapid notification through current contact lists and existing guidelines for environmental protection.

(ix) Importance of Public Information During Response

An initial lack of communication on the part of the company very nearly resulted in major industrial action by the employees, and sparked protests from surrounding communities when the contaminated debris was being held on the company's premises. Once people were fully briefed on the situation, protests ceased. This highlights the importance of regular briefing and information updates to the public when any type of emergency response function is being carried out.

CONCLUSION

Jamaica can consider itself "lucky" at the outcome of this incident. The illegal dumping resulted in no permanent environmental damage and the polluter willingly accepted responsibility for clean-up and disposal. Some of the problems highlighted by the spill are now being addressed, in particular the designation of hazardous waste disposal sites and a review of landfill site location.

The lessons learnt from this incident could form the basis for a comprehensive hazardous materials management programme, incorporating the preparedness programme already in place at the ODP.

It is hoped that this paper will help other developing countries to focus on similar problems which might be encountered in this type of incident.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance of Dr. A. Reid and Mr. Dave Virtue of Alcan Jamaica Company and Mr. Peter Lamm of the Underground Water Authority in the preparation of this paper, and that of the Canadian International Development Agency in attending the conference.

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"UNITED STATES ENVIRONMENTAL PROTECTION AGENCY OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE ENVIRONMENTAL RESPONSE TEAM'S GENERIC SITE HEALTH and SAFETY PLAN"

by

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INTRODUCTION

The United States Environmental Protection Agency's (USEPA) Environmental Response Team (ERT) was established in October 1978 to provide technical support to Regional On-scene Coordinators (OSC's), Regional Response Teams (RRT's), EPA Headquarters, and State Offices, as well as other federal and foreign governmental agencies, in the area of emergency environmental issues, such as chemical spills and uncontrolled hazardous waste sites.

This paper describes an IBM-PC computer program developed by the ERT to generate a Generic Site Health and Safety Plan (HASP) that complies with the Hazardous Waste Worker Protection Standards (29 CFR 1910.120) promulgated by the U. S. Department of Labor, Occupational Safety and Health Administration (OSHA).

BACKGROUND

The final rule for Hazardous Waste Operations and Emergency Response (29 CFR 1910.120) was published in the Federal Register by OSHA on March 6, 1989 and became effective on March 6, 1990. The rule regulates the safety and health of employees involved in cleanup operations at uncontrolled hazardous waste sites and in any emergency response to incidents involving hazardous substances. The standards require that a site safety and health plan be developed prior to the commencement of site activities. One of the ERT's functions is to review and/or develop site specific health and safety plans (HASP's) that are developed by the EPA regions or contractors for EPA. After reviewing several of these plans for the EPA regions, it became apparent that a guidance document could assist health and safety personnel in developing HASP's that meet the requirements of OSHA. The ERT has developed such a guidance -- the Generic Health and Safety Plan (HASP).

OBJECTIVES

The HASP has been developed with the following target objectives:

o To provide a standard format which is consistent with the OSHA's 29 CFR 1910.120 standard for hazardous waste site activities and emergency response.

o To allow for easy manipulation of standard text components for repetitive tasks common to most hazardous waste site investigations (i.e., drum sampling, well drilling, test pits, extent of contamination, etc.). This is helpful in defining and using standardized safe operating practices as required by the standard.

o To facilitate by automation contaminate specific information (i.e., TLV's, PEL, IDLH, vapor pressure, physical chemical properties, routes of exposure), appropriate monitoring devices, appropriate protective clothing, and selection of levels of protection.

o To provide field personnel with the ability to easily prepare a site specific HASP, which can be reviewed and approved by a qualified health and safety professional. This will ensure that field personnel are familiar with the plan through their involvement in the development process and allow for health and safety management resources to be used expeditiously.

The current system includes a manual, beginning with a Table of Contents and installation instructions, so that the program can be run on IBM-PC computer with 640 Kbytes of RAM. The HASP will generate a site specific safety plan using an automated decision-making process, which decreases the time normally required to retrieve and integrate data. The HASP will recommend the level of protection required (i.e., respirator, personnel protective equipment), based on the tasks being performed and the chemicals that may be encountered. At critical-decision making points in HASP, the user will be able to either accept the recommendations made by HASP, or to change or modify the required levels of protection. HASP includes standard protocols for "typical" waste remediation and assessment activities.

The base module of HASP is a mobile field usable version, containing a data base of information on 110 commonly occurring chemicals. The full version of HASP contains a data base with an additional 2,500 chemicals and will be available on an "as requested" basis, in the form of data packets. These data packets can then be appended to the field version of HASP, expanding the chemical data base available.

Consistent with the requirements outlined in the OSHA standard, the plan is organized in the following respective sections:

1.0 INTRODUCTION:

This section defines general applicability and responsibilities with respect to compliance with the Health and Safety programs.

2.0 KEY PERSONNEL/IDENTIFICATION OF HEALTH & SAFETY PERSONNEL:

This section addresses personnel and organizations critical to planned site activities.

3.0 TASK/OPERATION SAFETY AND HEALTH RISKS ANALYSIS:

This section defines the hazards and methods to protect personnel from those hazards identified in previous site work or from background information.

4.0 PERSONNEL TRAINING REQUIREMENTS:

Consistent with 29 CFR 1910.120, all site personnel are required to be trained in accordance with the standard paragraph e. At minimum, all personnel are required to be trained to recognize the hazards on-site, the provision of this HASP, and the key personnel.

5.0 PERSONNEL PROTECTIVE EQUIPMENT TO BE USED:

This section describes the general requirements of the EPA's designated Levels of Protection, and the specific levels of protection required for each task.

6.0 MEDICAL SURVEILLANCE REQUIREMENTS:

This section describes the medical surveillance activities that will take place during and at the completion of the project.

7.0 FREQUENCY AND TYPES OF PERSONNEL - AIR MONITORING/SAMPLING:

This section defines the general concepts of an air monitoring program and specific surveillance activities that will take place during the project.

8.0 SITE CONTROL:

This section defines measures and procedures for maintaining site control. Site control is an essential component in the implementation of the site health and safety program.

9.0 DECONTAMINATION PLAN:

This section will list the levels of protection required for the different tasks and provide a step-by-step representation of the personnel decontamination process for the required level of protection.

10.0 EMERGENCY RESPONSE/CONTINGENCY PLAN:

This section describes contingencies and emergency procedures to be implemented including: pre-emergency planning, lines of authority, emergency recognition/prevention.

11.0 CONFINED SPACE ENTRY PROCEDURES:

A confined space provides the potential for unusually high concentrations of contaminants, explosive atmospheres, limited visibility, and restricted movement. This section will establish requirements for safe entry into, continuous work in, and exit from confined spaces. Additional information regarding confined space entry can be found in 29 CFR 1926.21, CFR 1910 and NIOSH 80-106.

12.0 SPILL CONTAINMENT PROGRAM:

This section addresses actions to be implemented to contain or isolate any hazardous material in event of a spill.

CONCLUSION

The generic health and safety plan is currently being introduced to all EPA Regions and, after peer review within the Agency, will be available to the public.

The HASP was developed using the best technical and scientific information available at the time of printing. Health and safety professionals agreed on the logic decisions used by HASP, decisions which take a conservative approach in determining levels of protection. However, we caution the blind use of the HASP data, since sites and task situations differ, and the HASP may not reflect the site specific needs.

The HASP document is not intended to take the place of qualified health care and personnel. Knowledgeable individuals are able to produce a health and safety plan using HASP; however, the resulting plan should be reviewed and approved by qualified health and safety professionals prior to implementation of the plan.

ACKNOWLEDGEMENT

The authors express their appreciation to all members of the USEPA/ERT, USEPA, ERT's Research Engineering Analytical Contractor (REAC) Roy F. Weston, Edison, New Jersey for their many contributions and constant updating of our procedures.

DISCLAIMER

The mention of trade names or commercial products in this paper or the automated system is for illustration purposes and does not constitute endorsement or recommendation for use by the Environmental Protection Agency. Contents of this paper do not necessarily reflect the views and policies of the U. S. Environmental Protection Agency.

PROGRESS ON THE DEVELOPMENT OF SPILL ANALYTICAL TECHNIQUES

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SUMMARY

Since 1980, the Environmental Emergencies Technology Division of Environment Canada has conducted projects to develop and evaluate analytical systems for spill response. Research has focused on several different levels. Level I is defined as a system that is pocket-portable, level II is a person-portable system, level III is a vehicle-portable system, level IV is a mobile laboratory, and Level V is a fixed laboratory. Some work has also been done for oil spill analysis and detection systems for ship-mounted application and extensive work on remote sensing detection means.

The focus of development has been on levels II and level III systems as applied to Canada's chemical spill priority list. It should be emphasized that analytical developments have focused on all three media; air, water and soil. Numerous papers, most of which appear in the bibliography, have presented the developments that have occurred over the past 9 years. This paper will be a summary of these with particular emphasis on more recent developments.

PERSON-PORTABLE ANALYTICAL SYSTEM

Early work focused on the development of person-portable systems for air contaminant measurement. The HNU and OVA instruments were chosen and modified by the addition of meter scale overlays to provide direct field measurement of 60 chemicals. The HNU meter scale overlays are now commercially-available. The HACH kit was evaluated as to its utility for measuring inorganic chemicals in water and adaptation was made for measuring these same substances in soil. Current work on the person-portable analytical system has dealt with 2 projects: first, continuing development of a person-portable analytical kit (PPAK) and second, surveying and evaluation of available equipment. Each will be summarized briefly in the following section.

A) Person-Portable Analytical Kit (PPAK)

Work has been continuing on a Person Portable Analytical Kit for on-site analysis of chemicals in soil and/or water in which a single known chemical is involved. The existing system uses colorimetric and titrimetric techniques. The present kit can be used to quantify approximately 70 chemicals from the priority list in water and 60 in soil. The kit also has the capability for quantitative testing of approximately 85 non-priority chemicals in water. Information required for the determination of concentrations of environmental contaminants with the kit is detailed in Environment Canada Report EE-110 (Goldthorp et al., 1989).

B) Survey/Evaluation of Portable Instrumentation for Field Use

A survey has been completed of available person-portable analytical systems which are directly field useable and provide quantitative results for a number of chemicals from Environment Canada's spill priority listing. The inclusion of instruments which satisfy the aforementioned criteria is based solely on information supplied by the manufacturers and distributors.

The information obtained for each instrument, or series of instruments, includes the full address of both the manufacturer and the Canadian distributor (if one exists), the name of the instrument and the detection method employed. Also included is a description of the instrument such as display characteristics, alarms, detection levels, response time, accuracy, operating conditions, power requirements and ranges for detectable compounds. The physical dimensions of weight and size as well as the price in Canadian dollars follow the instrument description. The survey has been published as an Environment Canada Report (Goldthorp, 1989).

In the survey, the listings are alphabetical according to the manufacturer. Charts which allow easy cross referencing are also included in the review. The charts allow the user to select a compound (listed alphabetically) and determine which instruments can be used for quantitative analysis. Charts are also available for selection of instrumentation using a specific analytical technique or for use when chemicals are found in different environmental media (namely air, water and soil).

As stated earlier, all the information in this survey is supplied by the manufacturers and distributors.

An evaluation of selected instrumentation listed in this survey has been initiated and will include the following points:

-portability
-rapidity
-accuracy

-sensitivity
-simplicity of use, especially when wearing protective clothing (e.g. gloves, full face shield, etc.)
-simplicity of maintenance
-adaptability for use over a wide range of climatic conditions (e.g. temperature, humidity, etc.).

VEHICLE-PORTABLE ANALYTICAL SYSTEM

Work has been continuing on a vehicle-portable analytical system for on-site analysis of chemicals in air, soil, water and/or on various surfaces in which a single (known or unknown) chemical or a mixture of chemicals is involved. The development system has undergone major changes in the last year. The old gas chromatograph has been replaced by a Hewlett-Packard 5890 GC coupled to a HP5971A MSD (Mass Selective Detector). The 5890 GC is also equipped with a second injection port, column and flame ionization detector; a temperature programmable injection port (cryogenic focusing); an autoinjector; and a Chemstation. The latter is a computer which contains a library of 43,000 mass spectra which can be searched to aid in the identification of unknown pollutants. Retention indices are also needed to improve the reliability of identification.

Other equipment which has been installed in the vehicle includes a Suprex SFE/50 Supercritical Fluid Extraction instrument. This device employs carbon dioxide or other gases above their critical points to extract organic chemicals from solids. The unit enables extraction of samples in minutes at efficiencies approaching those achieved in days using conventional techniques. In addition, the unit can concentrate samples to a great degree, thereby increasing the capability of analysis to lower concentrations.

Work is now under way to calibrate the new systems. Work is required to develop additional sampling and concentration techniques.

This new equipment will enable the vehicle-portable system to provide analysis equivalent to that of a fixed laboratory but in under 2 hours and directly on site. The importance of fast-processing directly on-site for emergencies can not be over-emphasized.

SURVEY OF LABORATORY ANALYTICAL METHODS

A survey of analytical chemical methods which can be used in the vehicle-portable analytical systems for the quantitative analysis of chemicals in various environmental media, has been done (Vandenberg, 1989b). The survey is presented in a manual which is divided into three volumes with 410 analytical methods included.

Volume 1 is a summary of Volumes 2 and 3. The first volume contains the indices for all the methods and a short summary of each method including such information as the procedure, the range and precision, the source and the environmental media to which the method is applied. Volume 2 contains the more detailed 135 methods for the analysis of chemicals in air. Volume 3 contains 170 methods for the analysis of chemicals in water and 105 methods for the analysis of chemicals in soil, also included are the sample collection and extraction methods. A summary of these methods is also available as Environment Canada manuscript report EE-115 (Vandenburg, 1989b).

SHIP AND AIRCRAFT DETECTION

A fluorometric submarine for measuring oil (and other fluorescing chemicals) in water has been developed. This unit provides direct read-out of oil concentrations in parts-per-billion on a computer terminal. The submarine can be towed at speeds up to six knots.

A large amount of work has been done in cooperation with the Canada Centre for Remote Sensing on the application of remote detection techniques to oil spills. Some of these same techniques will be applicable to chemical spills, and future work will be done to assess this transfer of technology. Numerous reports detail the findings, however a summary can be found in O'Neil et al.

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COMMON HEALTH AND SAFETY PLAN ERRORS

by

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INTRODUCTION:

The U.S. Environmental Protection Agency's, Environmental Response Team (ERT), was established in October 1978 to provide technical assistance to On-Scene Coordinators (OSC's), National Response Team (NRT), Regional Response Team (RRT's), EPA Headquarters and Regional Offices, as well as other United States and Foreign Governmental Agencies, in the area of environmental emergency issues, such as chemical spills and uncontrolled hazardous waste sites.

In addition to field response activities, one of the primary functions of the Safety and Air Surveillance Section (SASS) is to serve as the primary technical expert for EPA's Office of Solid Waste and Emergency Response in the area of hazardous waste occupational health and safety. This not only requires on-site occupational health and safety activities, but also requires program reviews and evaluations.

The Federal standard, which requires each specific site to have a Health and Safety Plan (HASP) before site activities commence, is the Occupational Health and Safety Administration's 29 CFR 1910.120. In addition to outlining 29 CFR 1910.120(b)(4) health and safety plan requirements, this paper will address the most commonly-made errors occurring in HASPs based on the author's experiences. The paper will conclude with a summary of US EPA, Office of Solid Waste and Emergency Response Directive Number 9285.8-02 entitled,"U.S. EPA SARA Title I Section 126 Health and Safety Guidelines." This document was developed by ERT and is used by the author to review HASPs and evaluate field activities.

HEALTH AND SAFETY PLAN (HASP) REQUIREMENTS:

In addition to various programmatic and training requirements, 29 CFR 1910.120 requires that a HASP be developed for all Hazardous Waste Site Activities prior to on-site activities. A HASP provides several key functions for site operations. First, it is designed to provide necessary information to site workers in order to assure them of a safe and healthful workplace. Second, it provides a site chain-of-command for both normal and emergency operations. Third, the HASP provides the necessary information, monitoring programs and task descriptions to insure safe and healthful conditions for the surrounding environment.

Section 29 CFR 1910.120(b)(4),(March 6, 1989, Federal Register, Vol. 54, No. 42, pages 9294-9336) requires the following information be addressed in a HASP:

*KEY PERSONNEL
*SITE CONTROL
*MEDICAL SURVEILLANCE
*DECONTAMINATION
*EMERGENCY RESPONSE PLAN
*AIR MONITORING/SAMPLING TECHNIQUES
*RISK ANALYSIS PER TASK
*TRAINING
*CONFINED SPACE
*SPILL CONTAINMENT PROGRAM
*PERSONAL PROTECTIVE EQUIPMENT PER TASK

COMMON ERRORS:

Since one of the primary functions of the SASS is to perform, develop, implement and review technically complex and unique Occupational Health and Safety protocols, contingency plans and site safety plans, the author wishes to share his experiences with regard to reviewing HASPs. Therefore, the following is a summary of the most commonly found errors in HASPs:

1. MULTIPLE PLANS. The ERT recommends that only one HASP per site is applicable. This plan should be that of the lead agency or responsible party. Although numerous contractors and subcontractors may be working on one site, it is the lead agency's/responsible party's role to set the minimum allowable health and safety protocols for the various site activities.

2. OUTDATED PLANS. Since site activities can vary in duration from a few days to years, the site plan should be reviewed and updated on a regular basis. It is recommended that this be one of the primary functions of the Site Safety Officer, since misinformation to the site workers can lead to a severe injury or accident.

3. TASK/OPERATION RISK ANALYSIS. Risk analysis is to be per task or operation, not just for the chemicals present. The risk is based on a number of factors such as: routes of exposure; affected medias; chemical contaminants of concern; and potential concentrations. In addition, this section of the HASP should identity the following:

a. SAMPLING HAZARD ANALYSIS. These are the potential hazards per sampling task. For example, groundwater sampling generally has the potential for the following hazards to be present: exposure to volatile organic vapors; back strains due to equipment usage; falls due to slippery surfaces; and shock from electrical equipment.

The plan should list corrective measures to minimize sampling hazardous. For example, the above-mentioned groundwater sampling hazard might be minimized by listing the following information in the HASP: monitor breathing zones for volatile organics; employ proper lifting and bailing techniques; remove purged water and wear correct boots; and/or use a ground fault interrupter when electronics may be exposed to moisture.

b. CHEMICAL HAZARD ANALYSIS. In order to evaluate the chemical hazards involved with a specific task/operation, the following information needs to be present in the HASP: source of potential chemical contaminants; PEL/TLV/IDLH or appropriate chemical information available; routes of contamination; monitoring methods for the chemicals; and routes of exposure.

c. PHYSICAL HAZARD ANALYSIS. In addition to the chemical hazards information, the HASP needs to address the risk to humans for each compound in its various forms. For example, if benzene is potentially present, then the following information should be included in the HASP: (1) benzene vapor irritates human mucous membranes, inhalation causes headache, breathing difficulties and unconsciousness; (2) benzene liquid irritates human mucous membranes and is harmful if swallowed.

d. FIRE AND EXPLOSION HAZARD RISKS. This information should be considered by compound and form. For example, benzene vapor will flashback and explodes in confined spaces, while benzene liquid will flashback and/or ignite.

4. PERSONAL PROTECTIVE CLOTHING. At a minimum, the HASP should contain all the appropriate standard operating procedures and the appropriate level per individual site task.

5. MEDICAL SURVEILLANCE . The HASP shall address the medical surveillance needs for the specific site. For example, the following may be required for all site personnel: completed medical and work history; physical

exam; pulmonary function test; EKG; eye exam; audiometry; urinalysis; and blood chemistry.

6. CONFINED SPACE. Since the HASP is required to address Confined Space, it is recommended that if Confined Space work is not applicable for a specific site, it be stated in the HASP. A Confined Space/Work Area is an area that is not designed or intended for normal human occupancy with limited egress and poor ventilation. Therefore, many buildings or warehouses at a hazardous waste activity may meet the criteria for being a Confined Space.

While other errors are often found during HASP reviews, ranging from not listing the necessary health and safety training requirements to forgetting to include daily tailgate safety meetings, the above six are the most commonly-found errors. Of the six mentioned, the most common one is that the HASP does not identify the task/operation safety and health risk analysis. Routinely, the HASPs will only address the chemical hazard information per specific chemical and not address the task at all.

HEALTH AND SAFETY AUDIT GUIDELINES:

In order to provide technical assistance to federal, state, and local agencies in the area of site safety program reviews, ERT developed Health and Safety Audit Guidelines for Superfund Amendments and Reauthorization Act (SARA) Title I, Section 126 (OSWER Directive No. 9285.8-02) hazardous waste site and emergency response activities. This document covers the following major topics: Preliminary Evaluations; Written Health and Safety Plan Review; Health and Safety Field Review; and Off-Site Emergency Response Review.

1. PRELIMINARY EVALUATIONS. The Preliminary Evaluation (PE) is to be conducted prior to site activities and is an ideal opportunity to collect important background information regarding a site. At a minimum, the PE should address the following: site location and accessibility; job function and duration of work; potential site hazards; pathways of hazardous substance and their chemical and physical properties; and present status of emergency teams for on-site response.

Pathways of hazardous substances should indicate site media that is contaminated; consider the physical and chemical properties of on-site contaminants; and indicate dispersion pathways.

2. WRITTEN HEALTH AND SAFETY REVIEWS. At a minimum, a HASP must contain the following topics in order to meet

the OSHA standard: key personnel; risk analysis; task and operation; site control; medical surveillance; personal protective equipment; confined space entry; spill containment; employee training; emergency response plan; and frequency and types of air monitoring.

For example, the personal protective equipment (PPE) section addresses the required information by asking appropriate questions. Does the HASP prescribe Specific PPE ensembles per task? Does the HASP contain/reference a comprehensive written PPE program?

3. HEALTH AND SAFETY FIELD REVIEWS. While a "paper review" of a HASP will determine if a plan contains all the required topics, it will not determine if the plan is appropriate for identified site activities. It is recommended that a site specific audit be conducted of both site management and workers to determine if the HASP is appropriate for the stated activities. The following identify the topics to be covered in a field review through a question and answer format: informational programs; site control; training; medical surveillance; work practices; monitoring; drum handling; decontamination; emergency response; illumination; and sanitation.

For example, the illumination portion of the HASP should indicate if additional lighting will be provided in dimly lit areas and the field review should verify.

4. OFF-SITE EMERGENCY RESPONSE REVIEW. While this section is not applicable for hazardous waste site activities, it was written to help first responders (i.e., fire or police) to evaluate their own health and safety program, in accordance with 29 CFR 1910.120(q).

CONCLUSION:

The author hopes that the reader found these examples of the most-commonly made errors useful. Copies of the U.S. EPA SARA TITLE I SECTION 126 HEALTH AND SAFETY AUDIT GUIDELINES (OSWER Directive No. 9285.8-02) are available from the U.S. EPA Publication Office, Center for Environmental Research Information, Cincinnati, Ohio 45268 by asking for publication number EPA/540/G-89/010. In addition, this document is archived with the National Technical Information Service from which it may be purchased by telephoning 703-487-4650.

DEVELOPMENT OF A NEW CHEMICAL SPILL PRIORITY LIST

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INTRODUCTION

In 1979, the Environmental Emergencies Branch (as it was then known) embarked on an accelerated program to improve the response and countermeasures technology for spills of materials other than oil. As an essential part of this program, a methodology was devised to develop a priority list of chemicals. A list of 150 chemicals was compiled of hazardous materials that had significant potential as spills in Canada. This list was then used to develop specialized countermeasures, analytical techniques and spill manuals. Individual manuals called EnviroTIPS were prepared for the first 50 priority substances. Tests of the utility of the priority list showed that a large portion of the spills were those of the higher priority substances.

Statistical spill data are extremely useful for setting priorities and identifying project needs for spill prevention and preparedness. This was recognized in 1972 and a database was developed to consolidate all Canadian spill data. This database is known as NATES, short for National Analysis of Trends in Emergencies System.[1] Table 1 shows the type of data that can be extracted from the system for chemical spills alone. This table covers chemical spills from 1974 to 1984 and was used to develop the current priority list. The NATES database now contains data on over 40,000 spill events. About 70% of these spill events are related to oil and petroleum products. About 20% involve wastes and aggregate materials. Only about 10% involve the spillage of "pure" chemicals.

THE FIRST SPILL PRIORITY LIST

The first spill priority list was developed in 1980.[2,3] Lists of the top 10, 50 and 150 were developed. Table 2 is the 1980 priority list of 150 substances. Several mathematical approaches to the development of the priority list were tried, however it was found that a simple ranking of supply volume, reported spill frequency, historical spill volumes and toxicity could result in a satisfactory list. The main objective was to identify the minimum number of chemicals that would account for the maximum number of spills. The use of the list would be as noted above, to act as a focus for the development of countermeasures, analytical methods and spill manuals.

Table 1 **SPILL OF CHEMICALS 1974-1984** Data from NATES

CHEMICAL	NUMBER OF SPILLS	VOLUME(t)
Acetic acid	9	73.25
Acetic anhydride	8	1.51
Acetone	4	9.93
Acetylene	1	0.01
Acrylonitrile	1	4.6
Aldrin	2	1.32
Aluminum phosphate	3	8.50
Aluminum silicate	1	10.5
Aluminum sulfate	9	122.2
Aminocarb	12	55.77
Ammonia,anhydrous	107	466.12
Ammonium chloride	1	0.7
Ammonium hydroxide	15	127.64
Ammonium nitrate	63	4237.64
Ammonium phosphate	5	144.4
Ammonium stearate	1	0.1
Ammonium sulfate	8	261.7
Aniline	1	0.1
Arsine	1	0.0
Asbestos	15	310.47
Atlox	1	0.2
Atrazine	2	0.85
Azinphos-methyl	1	0.0
Barban	1	0.01
Barium sulfate	1	820.0
Benzene	12	13.76
Benzoic acid	2	34.5
Benzotrifluoride	1	50.48
Bromoform	1	0.01
Butanol	1	2.23
Butyl formate	1	0.04
Calcium arsenate	1	0.05
Calcium carbide	1	1.8
Calcium chloride	20	3678.84
Calcium cyanide	1	0.09
Calcium fluoride	1	1.00
Calcium hydroxide	17	360.13
Calcium hypochlorite	4	17.41
Calcium nitrate	1	1.8
Calcium oxide	12	530.94
Calcium phosphate	3	103.6
Carbaryl	2	69.60
Carbofuran	4	0.06
Carbon dioxide	1	0.0
Carbon tetrachloride	1	1.8
Cesium 137	3	0.00
Chlordane	2	0.00

Table 1 ctd. Spills of Chemicals 1974-1984

CHEMICAL	NUMBER OF SPILLS	VOLUME(t.)
Chlorhydrin	1	0.8
Chlorine	36	120.97
Chlorine dioxide	2	0.3
Chloroaniline	1	0.5
Chorodifloromethane	1	0.27
Chlorophenol	1	0.04
Chromic acid	7	8.82
Cobalt hydroxide	1	5.1
Cobaltous nitrate	1	0.9
Copper cyanide	1	2.2
Copper oxide	1	0.0
Copper sulfate	5	22.9
Cresols	2	12.7
Cresylic acids	2	0.07
Cyanides	7	2.0
Cyanogen bromide	1	0.00
Cyclohexane	1	0.11
Cyclohexylamine	1	0.07
2,4-D	37	129.03
Decyl octyl phthalate	1	0.1
Diallate	3	0.08
Diazinon	4	0.23
Dicamba	2	0.17
Dichlorvos	1	0.1
Dieldrin	1	0.00
Diethanolamine	1	0.2
Diethyl methyl amine	1	0.0
Diethylamine	2	1.8
Dinitroamine	2	0.0
Dinoseb	1	0.91
Diphenyl	1	1.3
Diphenyl amine	1	0.03
Diphenyl oxide	1	1.5
Diquat	2	0.0
Ethanol	3	50.79
Ethyl acrylate	3	1.13
Ethyl amine	1	1.3
Ethyl benzene	4	0.79
Ethyl chloride	2	0.2
2-Ethylhexanol	1	100.7
Ethyl mercaptan	6	0.01
Ethylene	2	178.5
Ethylene dichloride	1	781.0
Ethylene glycol	31	593.83
Fenitrothion	49	100.47
Ferric chloride	8	1004.47
Ferric hydroxide	2	5.0
Ferric oxide	5	22.7
Ferric sulfate	1	0.5

Table 1 ctd. Spills of Chemicals 1974-1984

CHEMICAL	NUMBER OF SPILLS	VOLUME(t.)
Ferrous sulfate	1	21000.0
Flamprop-methyl	3	0.16
Fluoboric acid	1	0.0
Formaldehyde	10	41.05
Formic acid	1	0.2
Glyphosate	1	0.00
Heavy water	2	22.2
Hexane	5	8.03
Hydrazine	3	4.52
Hydrochloric acid	123	3335.13
Hydrofluoric acid	5	0.68
Hydogen peroxide	7	0.71
Iridium 192	1	0.0
Isopropanol	4	9.27
Lead oxide	2	2.1
Lignin sulfonate	5	181.97
Lindane	1	0.00
Lithium bromide	1	0.13
Magnesium hydroxide	1	10.5
Magnesium oxide	1	5.0
Malathion	7	0.29
Maleic anhydride	1	2.8
Maneb	1	1.28
MCPA	5	0.91
Methomyl	1	0.0
Methyl ethyl ketone	4	7.66
Methyl ethyl ketone peroxide	1	0.0
Mercuric sulfide	1	29.9
Mercury	11	19.90
Methyl methacrylate	3	3.40
Methane	1	0.06
Methanol	18	734.75
Methoxychlor	1	0.05
Methyl chloride	2	2.5
Methyl hexyl ketone	1	0.94
Methylamine	1	5.3
Methylene chloride	4	6.15
Naphthalene	3	6.40
Neopentyl glycol	1	0.01
Nickel carbonyl	1	0.3
Nitric acid	40	139.60
Nitroaniline	1	0.00
Nitrogen dioxide	3	0.00
Nitrogen	3	1.85
Nitrous oxide	1	0.6
Nonane	1	0.01
Nonylphenol	2	8.78
Oxygen,liquified	5	24.19

Table 1 ctd. Spills of Chemicals 1974-1984

CHEMICAL	NUMBER OF SPILLS	VOLUME(t.)
Paraquat	2	43.61
Parathion	1	0.01
Phosphamidon	8	15.6
Pentachlorophenol	19	109.34
Perchloroethylene	10	15.50
Phenolsulfonic acid	2	22.6
Phenol	10	14.2
Phenylmercury acetate	1	0.01
Phenyl diamine (para)	1	0.0
Phosphorus	16	45.52
Phosgene	1	0.0
Phosphorus pentoxide	1	0.6
Phosphine	1	0.00
Phosphoric acid	12	36.2
Phthalic anhydride	3	7.2
Picloram	3	0.53
Polychlorinated biphenyls	334	89.24
Potassium aluminate	1	0.7
Potassium carbonate	1	100.0
Potassium chloride (potash)	31	11836.01
Potassium cyanate	1	0.01
Potassium hydroxide	2	1.2
Potassium permanganate	4	9.80
Propylene chlorohydrin	1	8.91
Propionic acid	1	2.0
Propylene	1	9.1
Proplylene glycol	1	8.3
Propylene oxide	2	22.02
Pyridine	2	0.01
Sodium,metal	1	0.5
Sodium aluminate	1	14.3
Sodium arsenite	1	0.0
Sodium borohydride	1	4.5
Sodium carbonate	3	25.04
Sodium chlorate	23	7676.94
Sodium chromate	1	0.02
Sodium cyanide	3	82.6
Sodium dithionite	2	28.9
Sodium fluoride	1	0.2
Sodium hydroxide	92	8225.74
Sodium hydrosulfide	2	2.28
Sodium hypochlorite	11	58.05
Sodium nitrate	1	2.5
Sodium silicate	1	3.8
Sodium stearate	1	0.05
Sodium sulfite	4	29.15
Sodium thioglycolate	1	0.2
Styrene	24	5001.29
Sulphur	68	69720.01

Table 1 ctd. Spills of Chemicals 1974-1984

CHEMICAL	NUMBER OF SPILLS	VOLUME(t.)
Sulphur chloride	3	3.51
Sulphur dioxide	16	89.5
Sulphuric acid	155	13362.47
Stannic chloride	1	0.0
Sulfuryl chloride	2	4.4
2,4,5-T	2	0.24
Terephthalic acid	1	0.18
Terphenyl	2	1.06
Tetraethyl lead	4	71.9
Tetrahydronapthalene	1	0.09
Thallium sulphate	1	0.03
Thioglycolic acid	1	0.0
Thiram	1	0.3
Titanium dioxide	2	0.5
Toluene 2,4-diamine	2	11.42
Toluene diisocyanate	7	1.10
Toluene	13	105.21
Tributylphosphate	1	0.3
Trichlorfon	3	2.6
Trichloroethane	4	0.81
Trichloroethylene	1	0.13
Triethanolamine	1	0.19
Trifluralin	9	4.59
Trimethyl amine	1	1.5
Trimethylene bromide	1	0.4
Trinitrotoluene	1	17.0
Uranyl nitrate	3	0.21
Vinyl acetate	8	7.41
Vinyl chloride	31	183.39
Xylenes	14	46.59
Yellow cake	1	0.21
Zinc bromide	1	0.38
Zinc chloride	1	12.8
Zinc cyanide	1	0.2
Zinc oxide	3	54.5
Zinc phosphate	1	0.9
Zinc stearate	1	0.0
Zinc sulphate	3	68.4

The first priority list was successful in that a few number of chemicals could account for many spills. The first 10 chemicals accounted for 37% of the reported spill events by number, 83% of the spill volume, and 50% of the volume of chemical supply in Canada. Figure 1 shows the utility of the list as applied to the spill history of 1980. The "utility" is a mathematical term to describe the usefulness or applicability of a particular formula or in this case the results of a mathematical exercise.

Table 2 1980 List of The 150 Top Priority Chemicals

1,1,1-Trichloroethane
1,3-Butadiene
2-Ethylhexanol
2,4-Dichlorophenoxyacetic Acid (2,4-D)
2,4-Toluene Diisocyanate
Acetic Acid
Acetic Anhydride
Acetone
Acetylene
Acrylonitrile
Adipic Acid
Aluminum Chloride
Aluminum Hydroxide
Aluminum Sulfate
Aminocarb Pesticide (Matacil)
Ammonia
Ammonium Chloride
Ammonium Nitrate
Ammonium Phosphates
Ammonium Sulfate
Arsine
Barium Sulfate
Benzene
Benzoic Acid
Borax
Boric Acid
Butanols
Butylene
Butyraldehydes
Calcium Carbide
Calcium Carbonate
Calcium Chloride
Calcium Hypochlorite
Calcium Oxide/Hydroxide
Calcium Phosphate
Caprolactam
Carbaryl
Carbofuran Pesticides
Carbon Dioxide
Carbon Disulfide
Carbon Tetrachloride
Chlordane
Chlorine
Chloroform
Copper Sulfate
Cresols
Cyclohexane
Dicamba
Dichlorobenzene
Dimethyl Ether
Dimethyl Terephthalate
Dinoseb
Diphenylmethane-4,4'-Diisocyanate
Ethanol
Ethanolamine
Ethylbenzene
Ethylene Dibromide
Ethylene Dichloride
Ethylene Glycol
Ethylene Oxide
Ethylene
Fenitrothion
Ferric Chloride
Fluorochloromethanes
Formaldehyde
Formic Acid
Hydrazine
Hydrogen
Hydrogen Chloride/Acid
Hydrogen Fluoride/Acid
Hydrogen Peroxide
Hydrogen Sulfide

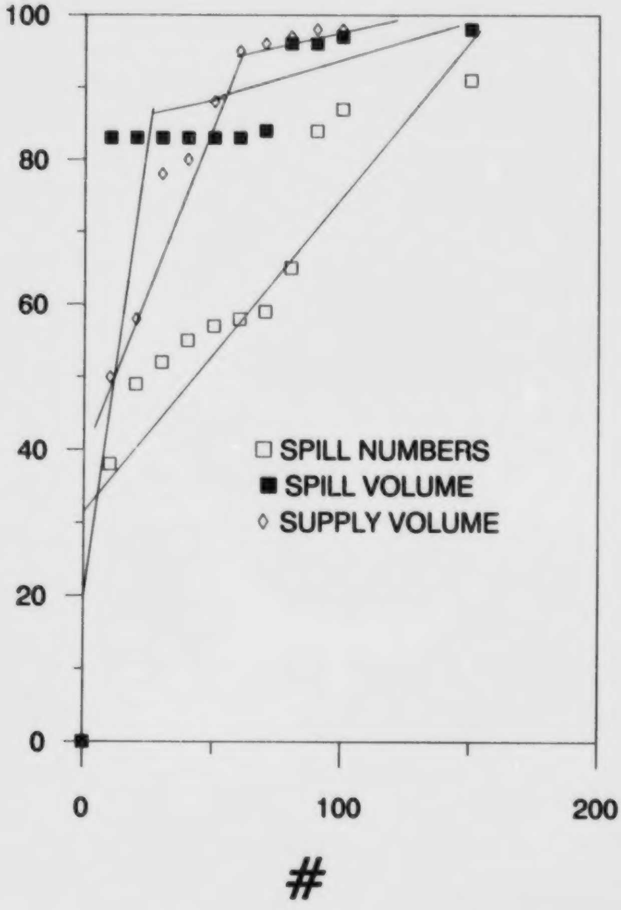
Zinc Oxide

Isopropanol
Isopropylbenzene
Latex
Lead Chromate
Lead Oxide
Magnesium Hydroxide
Malathion
Maleic Anhydride
MCPA
Mercury
Methanol
Methyl Methacrylate
Methyl Ethyl Ketone
Methyl Isobutyl Ketone
Mathylamines
Methylene Chloride
Morpholine
n-Hexane
Naphtha
Natural Gas
Nitric Acid
Nitrilotriacetic Acid
Nitroglycerine
Nonyl Phenol
PCBs
Pentachlorophenol
Perchloroethylene
Phenol
Phosphoric Acid
Phosphorus
Phthalic Anhydride
Potash (Potassium Chloride)
Potassium Hydroxide
Potassium Sulfate
Propylene Glycols
Propylene Oxide
Propylene
Sodium Aluminate
Sodium Arsenite
Sodium Borohydride
Sodium Carbonate
Sodium Chlorate
Sodium Chloride
Sodium Cyanide
Sodium Dichloroisocyanurate
Sodium Dichromate
Sodium Hydroxide
Sodium Hydrosulfide (Dithionite)
Sodium Hypochlorite
Sodium Phosphates
Sodium Silicates
Sodium Sulfate
Sodium Sulfite
Styrene (Monomer)
Sulfur
Sulfur Dioxide
Sulfuric Acid (and Oleum)
Sulfuryl Chloride
Tall Oil
Terephthalic Acid
Terphenyls
Tetraethyl Lead
Titanium Dioxide
Toluene
Triallate Pesticides
Trichlorofon Pesticides
Trifluralin Pesticides
Trinitrotoluene
Turpentine
Urea
Vinyl Acetate
Vinyl Chloride
Yellow Cake
Xylenes
Zinc Chloride
Zinc Sulfide

UTILITY OF THE 1980 PRIORITY LIST

FIGURE 1

PERCENTAGE ACCOUNTED FOR



DEVELOPMENT OF A NEW PRIORITY LIST

There are a number of motivations to developing a new priority list:

1. The spill history used for the first priority list was weak, with only 2 years of "good" data,
2. There may be a change in spill statistics due to a change in chemical use and transportation patterns,
3. In the first list, the use of toxicity information was weak, resulting in rather innocuous substances appearing high on the priority list,
4. The quantity of aquatic toxicity information has increased and this could be used as a separate consideration as "environmental" toxicity,
5. Although the earlier priority list was useful and had a high utility, there were some notable weaknesses such as the placement of PCBs above the top 50 line,
6. The availability of modern computer tools would enable a rapid and thorough re-evaluation, and
7. Ten years is an appropriate time to re-evaluate the list.

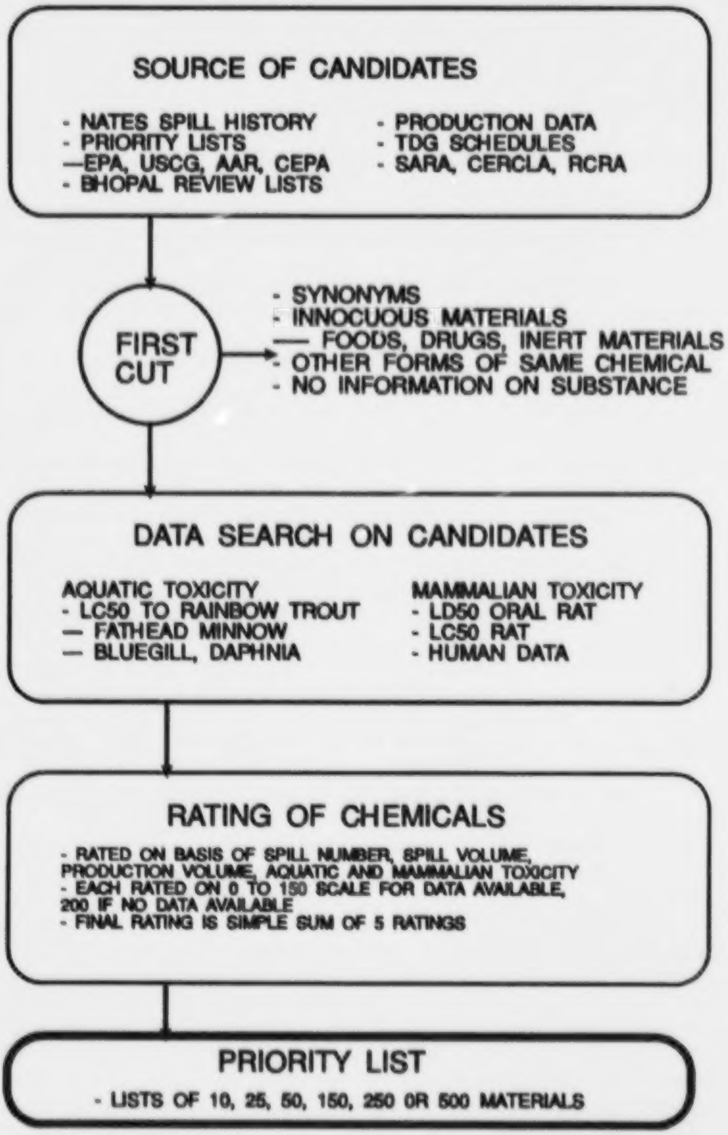
The objectives and principles for the new list development were set as the following:

1. The list should be developed in a systematic and mechanical fashion- that is the placement of individual compounds will only be due to the algorithm used and not on the basis of human judgement,
2. The high volume and frequently spilled chemicals should appear at the top of the list, but toxicity should affect their relative placement,
3. Toxicity will be divided into two considerations, mammalian and aquatic, encompassing both environmental and health concerns,
4. As in the first list, one of the prime objectives is to produce a list that contains as few chemicals as possible to deal with the largest number and volume of spills,
5. All possible candidates will be evaluated (only about 250 were considered in 1980),
6. Completely innocuous materials will be removed from consideration to ensure that they do not appear in any final priority lists, and
7. Several sizes of groupings (eg. 10, 25, 50, etc.) will be prepared to allow use for a variety of purposes.

The procedure employed for developing the new list is outlined in Figure 2. Candidate chemicals and hazardous substances other than oil, were taken from all known spill priority lists such as those published by the United States Environmental Protection Agency, The American Association of Rail Roads and The United States Coast Guard. Lists of materials from the Transport of Dangerous Goods Act were also included. The United States Environmental Protection Agency has published a "List of Lists" which includes substances

SUMMARY PROCESS FOR DEVELOPMENT OF REVISED PRIORITY LIST

FIGURE 2



SOURCE OF CANDIDATES

- NATES SPILL HISTORY
- PRIORITY LISTS
—EPA, USCG, AAR, CEPA
- BHOPAL REVIEW LISTS
- PRODUCTION DATA
- TDG SCHEDULES
- SARA, CERCLA, RCRA

FIRST CUT

- SYNONYMS
- INNOCUOUS MATERIALS
— FOODS, DRUGS, INERT MATERIALS
- OTHER FORMS OF SAME CHEMICAL
- NO INFORMATION ON SUBSTANCE

DATA SEARCH ON CANDIDATES

AQUATIC TOXICITY
- LC50 TO RAINBOW TROUT
— FATHEAD MINNOW
— BLUEGILL, DAPHNIA

MAMMALIAN TOXICITY
- LD50 ORAL RAT
- LC50 RAT
- HUMAN DATA

RATING OF CHEMICALS

- RATED ON BASIS OF SPILL NUMBER, SPILL VOLUME, PRODUCTION VOLUME, AQUATIC AND MAMMALIAN TOXICITY
- EACH RATED ON 0 TO 150 SCALE FOR DATA AVAILABLE, 200 IF NO DATA AVAILABLE
- FINAL RATING IS SIMPLE SUM OF 5 RATINGS

PRIORITY LIST

- LISTS OF 10, 25, 50, 150, 250 OR 500 MATERIALS noted in RCRA, SARA and CERCLA legislation. References 4 to 13 provide details on these. Most of these lists are also summarized in the Appendix, Table A4, "List Membership Comparison".

After the potential candidates were accumulated, they were reviewed for synonyms and substances that were just different forms of each other. This reduced the list by about 5%. All chemicals on the list were reviewed for toxicity and other forms of hazards such as flammability or explosiveness. Substances that showed no danger were removed. Similarly those substances that were human foods or drugs were also removed. These processes reduced the list by a further 10%.

Data on aquatic and mammalian toxicity were collected from standard reference sources. Aquatic data included the results of acute lethal toxicity testing on Rainbow Trout, Blue Gill, Fathead minnow and to Daphnia Magna. Aquatic data on similar species was collected if none of the above were available. Data was found for over 50% of the named compounds. Oral and inhalation toxicity to the rat were collected for the mammalian toxicity along with some human data. Data were available for over 90% of substances on the list.

To rank all the toxicity data for the final priority, the lowest typical value for aquatic and the lowest typical mammalian oral toxicity was assigned the value of 1 and the highest, the value of 150. Substances with no data were rated 200.

Similarly, the spill numbers, volume and supply volume of the chemicals were ranked between 1 and 150. Substances with no spill history or commerce data were rated 200. The sum of the ranking for each of the five categories (spill numbers, spill volume, supply volume, aquatic toxicity and mammalian toxicity) were simply added to yield an overall value. These overall values are then directly related to the order of priority, lowest number first. The top priority chemicals are listed in Table 3.

The utility of this new list was analyzed like the 1980 list and a graph of this is shown in Figure 3. The first 10 priority substances account for 43% of spill numbers, 25% of spill volume and 15% of supply volume. The first 50 substances account for 80% of spill numbers, 97% of spill volume and 65% of supply volume. The 150 top priority chemicals account for 97% of spill numbers, 98% of spill volume and 82% of supply volume. This utility is much higher than the previous priority list and easily satisfies the starting criteria.

Analysis of the priority lists shows that the differences between the old and new lists are not major. Only 14 of the top 50 are different, and the 14 fall in the next 150 priority materials. Order is somewhat different and the list achieves the goal of having higher toxicity materials appear at a higher priority level.

UTILITY OF THE 1990 PRIORITY LIST

FIGURE 3

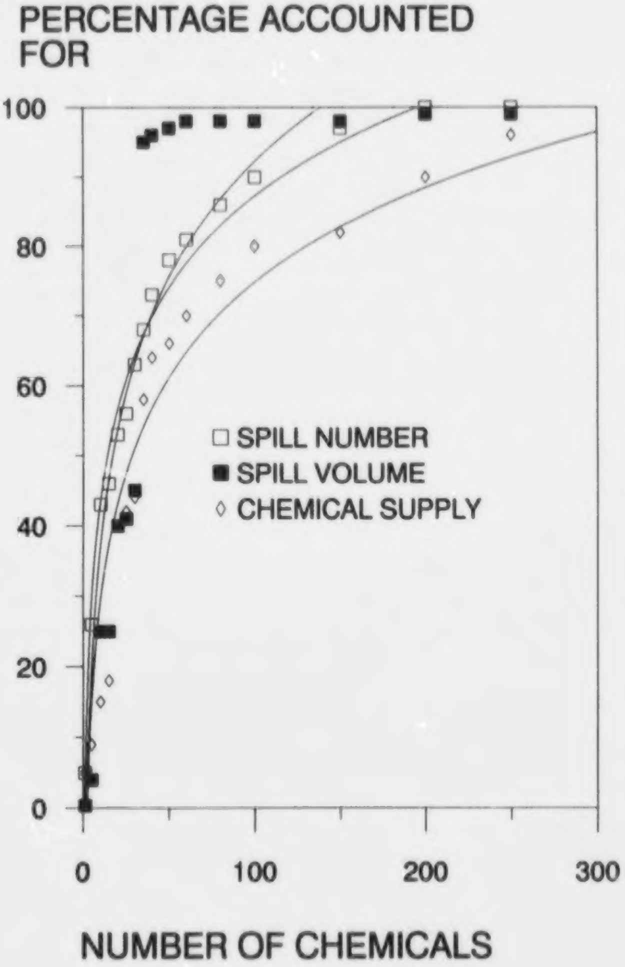


TABLE 3 THE 1990 CHEMICAL SPILL PRIORITY LIST

THE TOP TEN MATERIALS	
Ammonia	Potassium chloride
Chlorine	Sodium cyanide
Hydrochloric acid	Styrene
PCBs	Sulfuric acid
Pentachlorophenol	Tetraethyl lead

THE TOP TWENTY FIVE MATERIALS	
Ammonia	Phosphorus
Ammonium hydroxide	Potassium chloride
Ammonium sulfate	Sodium chlorate
Benzene	Sodium chloride
Calcium chloride	Sodium cyanide
Calcium hypochlorite	Sodium hydroxide
Chlorine	Styrene
Copper sulfate	Sulfuric acid
Formaldehyde	Tetraethyl lead
Hydrochloric acid	Toluene
PCBs	Xylene
Pentachlorophenol	Zinc sulfate
Phenol	

THE TOP 50 MATERIALS	
Acetic acid	Nonylphenol
Aldrin	PCBs
Aminocarb	Pentachlorophenol
Ammonia	Perchloroethylene
Ammonium hydroxide	Phenol
Ammonium nitrate	Phosphamidon
Ammonium phosphates	Phosphoric acid
Ammonium sulfate	Phosphorus
Benzene	Potassium chloride
Calcium chloride	Propylene oxide
Calcium hydroxide	Sodium carbonate
Calcium hypochlorite	Sodium chlorate
Carbon tetrachloride	Sodium chloride
Chlorine	Sodium cyanide
Copper sulfate	Sodium hydroxide
Ethylbenzene	Styrene
Ethylene dichloride	Sulfur
Ethylene glycol	Sulfur dioxide
Ethylhexanol	Sulfuric acid
Fenitrothion	Tetraethyl lead
Ferric chloride	Toluene
Formaldehyde	Vinyl acetate
Hydrochloric acid	Xylene
Methyl alcohol	Zinc sulfate
Nitric acid	2,4-dichlorophenoxyacetic acid (2,4-D)

Because of the restrictions on paper size for this conference. Full data tables will not be given. Basic data is found in the Appendix.

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APPENDIX

TABLE A1 LISTS OF THE TOP 10,25,50,150 AND 250 PRIORITY SPILL MATERIALS

TABLE A2 LIST OF THE TOP 500 PRIORITY CHEMICALS

TABLE A3 ANALYSIS OF THE TOP 500 CHEMICALS

TABLE A4 LIST MEMBERSHIP COMPARISON

TABLE A1 THE 1990 CHEMICAL SPILL PRIORITY LIST

THE TOP TEN MATERIALS

Ammonia
Chlorine
Hydrochloric acid
PCBs
Pentachlorophenol
Potassium chloride
Sodium cyanide
Styrene
Sulfuric acid
Tetraethyl lead

THE TOP TWENTY FIVE MATERIALS

Ammonia
Ammonium hydroxide
Ammonium sulfate
Benzene
Calcium chloride
Calcium hypochlorite
Chlorine
Copper sulfate
Formaldehyde
Hydrochloric acid
PCBs
Pentachlorophenol
Phenol
Phosphorus
Potassium chloride
Sodium chlorate
Sodium chloride
Sodium cyanide
Sodium hydroxide
Styrene
Sulfuric acid
Tetraethyl lead
Toluene
Xylene
Zinc sulfate

THE TOP 50 MATERIALS

Acetic acid
Aldrin
Aminocarb
Ammonia
Ammonium hydroxide
Ammonium nitrate
Ammonium phosphates
Ammonium sulfate
Benzene
Calcium chloride
Calcium hydroxide
Calcium hypochlorite
Carbon tetrachloride
Chlorine
Copper sulfate
Ethylbenzene
Ethylene dichloride
Ethylene glycol
Ethylhexanol
Fenitrothion
Ferric chloride
Formaldehyde
Hydrochloric acid
Methyl alcohol
Nitric acid
Nonylphenol
PCBs
Pentachlorophenol
Perchloroethylene
Phenol
Phosphamidon
Phosphoric acid
Phosphorus
Potassium chloride
Propylene oxide
Sodium carbonate
Sodium chlorate
Sodium chloride
Sodium cyanide
Sodium hydroxide
Styrene
Sulfur
Sulfur dioxide
Sulfuric acid
Tetraethyl lead
Toluene
Vinyl acetate
Xylene
Zinc sulfate
2,4-dichlorophenoxyacetic acid (2,4-D)

LIST OF THE TOP 150 MATERIALS

Acetic acid
Acetic anhydride
Acetone
Acetylene
Acrylonitrile
Aldrin
Aluminum sulfate
Aminocarb
Ammonia
Ammonium chloride
Ammonium hydroxide
Ammonium nitrate
Ammonium phosphates
Ammonium sulfate
Aniline
Atrazine
Azinphosmethyl
Benzene
Benzene hexachloride (Lindane)
Benzoic acid
Benzotrifluoride
Bromoform
Butyl alcohol
Calcium chloride
Calcium cyanide
Calcium hydroxide
Calcium hypochlorite
Calcium oxide
Calcium phosphate
Carbaryl
Carbofuran
Carbon tetrachloride
Chlordane
Chlorine
Chlorophenol
Chromic acid
Cobaltous nitrate
Copper cyanide
Copper sulfate
Cresol
Cyclohexane
Diazinon
Dicamba
Maneb
MCPA
Mercury
Methoxychlor
Methyl alcohol
Methyl chloride
Methyl ethyl ketone
Methyl methacrylate
Methylamine
Methylene chloride
Naphthalene
Nitric acid
Nitroaniline
Nitrogen (liquefied)
Nonylphenol
Oxygen (liquefied)
Paraquat
Parathion
PCBs
Pentachlorophenol
Perchloroethylene
Phenol
Phosphamidon
Phosphoric acid
Phosphorus
Phthalic anhydride
Picloram
Potassium chloride
Potassium cyanide
Potassium hydroxide
Potassium permanganate
Propionic acid
Propylene
Propylene glycol
Propylene oxide
Pyridine
Sodium carbonate
Sodium chlorate
Sodium chloride
Sodium cyanide
Sodium fluoride
Sodium hydrosulfite
Sodium hydroxide

LIST OF THE TOP 150 MATERIALS ctd.

Dichlorvos
Dieldrin
Diethanolamine
Diethylamine
Dimethylamine
Dinitramine
Dinoseb
Diphenyl ether
Diquat
Endrin
Ethyl alcohol
Ethyl chloride
Ethylbenzene
Ethylene
Ethylene dichloride
Ethylene glycol
Ethylene oxide
Ethylhexanol
Fenitrothion
Ferric chloride
Formaldehyde
Formic acid
Hexane
Hydrazine
Hydrochloric acid
Hydrofluoric acid
Hydrogen peroxide
Isopropyl alcohol
Lead oxide
Lignin sulfonate
Malathion
Maleic anhydride
Sodium hypochlorite
Sodium silicate
Sodium sulfite
Styrene
Sulfur
Sulfur dioxide
Sulfuric acid
Terephthalic acid
Tetraethyl lead
Thallium sulfate
Thioglycolic acid
Titanium dioxide
Toluene
Toluene-2,4-diamine
Toluene-2,4-diisocyanate
Tributyl phosphate
Trichloroethane
Trichloroethylene
Trichlorofon
Trifluralin
Trinitrotoluene
Uranyl nitrate
Vinyl acetate
Vinyl chloride
Xylene
Zinc chloride
Zinc cyanide
Zinc oxide
Zinc phosphate
Zinc sulfate
2,4,5-Trichlorophenoxyacetic . (2,4,5-T)
2,4-dichlorophenoxyacetic acid (2,4-D)

LIST OF THE TOP 250 MATERIALS

Acetaldehyde
Acetic acid
Acetic anhydride
Acetone
Acetone cyanohydrin
Acetylene
Acrolein
Acrylamide
Acrylonitrile
Aldicarb
Aldrin
Allyl alcohol
Aluminum chloride
Aluminum sulfate
Aminocarb
Ammonia
Ammonium chloride
Ammonium hydroxide
Ammonium nitrate
Ammonium phosphates
Ammonium sulfate
Aniline
Antimony trioxide
Arsenic acid
Arsine
Asbestos
Atrazine
Azinphos ethyl
Azinphosmethyl
Barium sulfate
Benzene
Benzene hexachloride (Lindane)
Benzoic acid
Benzotrifluoride
Borax
Bromoform
Brucine
Butyl alcohol
Butyl formate
Cadmium
Cadmium sulfate
Calcium arsenate
Calcium carbide
Calcium chloride
Calcium cyanide
Calcium hydroxide
Hydrochloric acid
Hydrocyanic acid
Hydrofluoric acid
Hydrogen peroxide
Hydrogen sulfide
Hydroquinone
Isodrin
Isopropyl alcohol
Kepone
Lead oxide
Lignin sulfonate
Magnesium hydroxide
Malathion
Maleic anhydride
Maneb
MCPA
Mercuric acetate
Mercuric chloride
Mercuric thiocyanate
Mercurous nitrate
Mercury
Methiocarb
Methoxychlor
Methoxyethylmercuric acetate
Methyl alcohol
Methyl chloride
Methyl ethyl ketone
Methyl methacrylate
Methyl parathion
Methylamine
Methylene chloride
Mevinphos
Naled
Naphthalene
Nickel carbonyl
Nitric acid
Nitroaniline
Nitrogen (liquefied)
Nitrogen dioxide
Nitrous oxide
Nonylphenol
Oxygen (liquefied)
Paraquat
Parathion
PCBs
Pentachlorophenol

LIST OF THE TOP 250 MATERIALS ctd.

Calcium hypochlorite
Calcium nitrate
Calcium oxide
Calcium phosphate
Carbaryl
Carbofuran
Carbon dioxide
Carbon disulfide
Carbon tetrachloride
Cesium 137
Chlordane
Chlorine
Chlorine dioxide
Chloroaniline
Chloroform
Chlorohydrin
Chlorophenol
Chlorpyrifos
Chromic acid
Cobaltous nitrate
Copper chloride
Copper cyanide
Copper sulfate
Coumaphos
Cresol
Cumene
Cyanogen bromide
Cyclohexane
Cycloheximide
Cyclohexylamine
DDT
Demeton
Diallate
Diazinon
Dicamba
Dichlone
Dichlorvos
Dicrotophos
Dieldrin
Diethanolamine
Diethylamine
Dimethylamine
Dinitramine
Dinitrocresols
Dinoseb

Perchloroethylene
Phenol
Phenolsulfonic acid
Phenyl mercuric acetate
Phosphamidon
Phosphoric acid
Phosphorus
Phosphorus pentoxide
Phthalic anhydride
Picloram
Potassium carbonate
Potassium chloride
Potassium cyanide
Potassium hydroxide
Potassium permanganate
Propargyl alcohol
Propionic acid
Propylene
Propylene glycol
Propylene oxide
Pyridine
Rotenone
Sodium aluminate
Sodium arsenite
Sodium azide
Sodium borohydride
Sodium carbonate
Sodium chlorate
Sodium chloride
Sodium chromate
Sodium cyanide
Sodium dichromate
Sodium fluoride
Sodium hydrosulfite
Sodium hydroxide
Sodium hypochlorite
Sodium nitrate
Sodium phosphate
Sodium silicate
Sodium sulfite
Strychnine
Styrene
Sulfur
Sulfur dioxide
Sulfuric acid

LIST OF THE TOP 250 MATERIALS ctd.

Dioxathion
Diphenyl
Diphenyl ether
Diquat
Disulfoton
Endosulfan
Endothall
Endrin
Ethion
Ethyl acrylate
Ethyl alcohol
Ethyl chloride
Ethyl mercaptan
Ethylamine
Ethylbenzene
Ethylene
Ethylene dichloride
Ethylene glycol
Ethylene oxide
Ethylhexanol
Fenitrothion
Ferric chloride
Ferric oxide
Ferrous sulfate
Flamprop-methyl
Fonofos
Formaldehyde
Formic acid
Glyphosate
Heavy water
Hexachlorobutadiene
Hexachlorophene
Hexane
Hydrazine
Terephthalic acid
Tetraethyl lead
Tetraethyl pyrophosphate
Thallium sulfate
Thioglycolic acid
Thiram
Titanium dioxide
Toluene
Toluene-2,4-diamine
Toluene-2,4-diisocyanate
Toxaphene
Tributyl phosphate
Trichloroethane
Trichloroethylene
Trichlorofon
Triethanolamine
Trifluralin
Trimethylene bromide
Trinitrotoluene
Uranyl nitrate
Urea
Vanadium pentoxide
Vinyl acetate
Vinyl chloride
Xylene
Zinc chloride
Zinc cyanide
Zinc oxide
Zinc phosphate
Zinc sulfate
2,3,4,6-Tetrachlorophenol
2,4,5-Trichlorophenoxyacetic .(2,4,5-T)
2,4-dichlorophenoxyacetic acid (2,4-D)
2,4-Dinitrophenol

THE TOP FIVE HUNDRED PRIORITY MATERIALS

Acetaldehyde
Acetic acid
Acetic anhydride
Acetone
Acetone cyanohydrin
Acetophenone
Acetyl chloride
Acetylene
Acrolein
Acrylamide
Acrylonitrile
Adipic acid
Adiponitrile
Alachlor
Aldicarb
Aldrin
Allyl alcohol
Allyl chloride
Aluminum chloride
Aluminum phosphate
Aluminum sulfate
Aminocarb
Amiton
Ammonia
Ammonium chloride
Ammonium hydroxide
Ammonium nitrate
Ammonium phosphates
Ammonium picrate
Ammonium stearate
Ammonium sulfamate
Ammonium sulfate
Aniline
Anthracene
Antimony trioxide
Arsenic
Arsenic acid
Arsenic pentoxide
Arsenic trioxide
Arsine
Asbestos
Atlox
Atrazine
Azinphos ethyl
Azinphosmethyl
Barban
Barium sulfate
Benzaldehyde
Benzene
Benzene hexachloride (Lindane)
Benzidine
Benzoic acid
Benzonitrile
Benzophenone
Benzotrifluoride
Benzoyl chloride
Benzyl alcohol
Benzyl chloride
Benzyl-n-butyl phthalate
Beryllium
Bisphenol A
Borax
Boric acid
Bromine
Bromoform
Brucine
Butadiene
Butyl alcohol
Butyl formate
Butyl mercaptan
Butylamine
Butylene
Butyraldehyde
Butyric acid
Cadmium
Cadmium chloride
Cadmium nitrate
Cadmium sulfate
Calcium arsenate
Calcium carbide
Calcium carbonate
Calcium chloride
Calcium cyanide
Calcium fluoride
Calcium hydroxide
Calcium hypochlorite
Calcium nitrate
Calcium oxide
Calcium phosphate
Camphor oil
Cantharidin
Caprolactam
Carbaryl
Carbofuran
Carbon dioxide
Carbon disulfide

THE TOP FIVE HUNDRED PRIORITY MATERIALS ctd.

- Carbon tetrachloride
- Carbonyl sulfide
- Carboxymethylcellulose
- Cesium 137
- Chlordane
- Chlorine
- Chlorine dioxide
- Chloroaniline
- Chlorobenzene
- Chlorodifluoromethane
- Chloroethylvinyl ether
- Chloroform
- Chlorohydrin
- Chlorophacinone
- Chlorophenol
- Chloroxuron
- Chlorpropham
- Chlorpyrifos
- Choline chloride
- Chromic acid
- Chromic sulfate
- Chromium
- Chromous chloride
- Cobaltous bromide
- Cobaltous chloride
- Cobaltous hydroxide
- Cobaltous nitrate
- Copper acetate
- Copper chloride
- Copper cyanide
- Copper nitrate
- Copper sulfate
- Coumaphos
- Cresol
- Crimidine
- Crotonaldehyde
- Cumene
- Cyanogen bromide
- Cyclohexane
- Cyclohexanone
- Cycloheximide
- Cyclohexylamine
- Dalapon
- DDT
- Decyl alcohol
- Decyl octyl phthalate
- Demeton
- Diallate
- Diazinon
- Dibromomethane
- Dibutyl amine
- Dibutyl ether
- Dicamba
- Dichlobenil
- Dichlone
- Dichlorodifluoromethane
- Dichloroethyl amino uracil
- Dichloroethyl ether
- Dichlorvos
- Dicrotophos
- Dieldrin
- Diethanolamine
- Diethyl chlorophosphate
- Diethyl phthalate
- Diethyl-m-toluamide
- Diethyl-p-nitrophenyl phosphate
- Diethylamine
- Diisopropylamine
- Dimefox
- Dimethoate
- Dimethyl ethyl amine
- Dimethyl phthalate
- Dimethyl sulfate
- Dimethylamine
- Dimethylaniline
- Dinitramine
- Dinitroaniline
- Dinitrobenzene
- Dinitrocresols
- Dinoseb
- Dioxathion
- Diphacinone
- Diphenyl
- Diphenyl ether
- Diphenylamine
- Diphenylmethane-4,4'-diisocyana
- Diquat
- Disulfoton
- Dithiobiuret
- Diuron
- Dodecylbenzenesulfonic acid
- Endosulfan
- Endothall
- Endrin
- Epichlorohydrin

THE TOP FIVE HUNDRED PRIORITY MATERIALS ctd.

EPN
Eptam
Ethanolamine
Ethion
Ethyl acetate
Ethyl acrylate
Ethyl alcohol
Ethyl chloride
Ethyl mercaptan
Ethylamine
Ethylbenzene
Ethylene
Ethylene dibromide
Ethylene dichloride
Ethylene glycol
Ethylene glycol monobutyl ether
Ethylene oxide
Ethylene thiourea
Ethyleneimine
Ethylhexanol
Fenitrothion
Fensulfothion
Ferric chloride
Ferric hydroxide
Ferric oxide
Ferrous sulfate
Flamprop-methyl
Fluenetil
Fluometuron
Fluoranthene
Fluorine
Fluoroacetamide
Fluoroacetic acid
Fonofos
Formaldehyde
Formic acid
Fumaric acid
Furazolidone
Furfural
Furfuryl alcohol
Glycerine
Glycidyl methacrylate
Glyphosate
Heavy water
Heptanol
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Hexachlorophene
Hexaethyl tetraphosphate
Hexaldehyde
Hexane
Hexanol
Hydrazine
Hydrochloric acid
Hydrocyanic acid
Hydrofluoric acid
Hydrogen
Hydrogen peroxide
Hydrogen sulfide
Hydroquinone
Iodomethane
Isobenzan
Isobutyl acrylate
Isobutyl alcohol
Isodrin
Isooctyl alcohol
Isophorone
Isopropyl alcohol
Isopropylmethylpyrazolyl dimet.car.
Isovaleraldehyde
Kepone
Lactonitrile
Lead arsenate
Lead chloride
Lead fluoroborate
Lead oxide
Lignin sulfonate
Lithium bromide
Magnesium hydroxide
Magnesium oxide
Malathion
Maleic acid
Maleic anhydride
Malononitrile
Maneb
MCPA
Melamine
Mephosfolan
Mercuric acetate
Mercuric chloride
Mercuric sulfide
Mercuric thiocyanate
Mercurous nitrate
Mercury

THE TOP FIVE HUNDRED PRIORITY MATERIALS ctd.

Methanesulfonyl fluoride
Methiocarb
Methoxychlor
Methoxyethylmercuric acetate
Methyl alcohol
Methyl amyl alcohol
Methyl bromide
Methyl chloride
Methyl ethyl ketone
Methyl ethyl ketone peroxide
Methyl hexyl ketone
Methyl isobutyl ketone
Methyl methacrylate
Methyl parathion
Methyl phenkapton
Methylamine
Methylene chloride
Methylstyrene
Metobromuron
Mevinphos
Mexacarbate
Monocrotophos
Morpholine
N,N-Dimethylaniline
N-Nitrosodiphenylamine
Naled
Naphtha
Naphthalene
Naphthol
Neopentyl glycol
Nickel carbonyl
Nickel chloride
Nicotine sulfate
Nitralin
Nitric acid
Nitrilotriacetic acid
Nitroaniline
Nitrobenzene
Nitrogen (liquefied)
Nitrogen dioxide
Nitroglycerin
Nitromethane
Nitrophenol
Nitropropane
Nitrosodimethylamine
Nitrotoluene
Nitrous oxide
Nonane
Nonanol
Nonylphenol
Octanol
Oleic acid
Oleum
Oxalic acid
Oxygen (liquefied)
Paraquat
Parathion
PCBs
Pentachlorobenzene
Pentachlorophenol
Perchloroethylene
Phenanthrene
Phenol
Phenolsulfonic acid
Phenyl mercuric acetate
Phenylenediamine
Phenylthiourea
Phorate
Phosgene
Phosmet
Phosphamidon
Phosphine
Phosphoric acid
Phosphorus
Phosphorus pentoxide
Phthalic anhydride
Picloram
Potassium aluminate
Potassium carbonate
Potassium chlorate
Potassium chloride
Potassium cyanide
Potassium dichromate
Potassium hydroxide
Potassium permanganate
Potassium sulfate
Propargyl alcohol
Propionaldehyde
Propionic acid
Propionic anhydride
Propylamine
Propylene
Propylene chlorohydrin
Propylene glycol
Propylene oxide
Pyridine

THE TOP FIVE HUNDRED PRIORITY MATERIALS ctd.

Pyrocatechol
Quinoline
Quinone
Resorcinol
Rotenone
Salicylic acid
Silver nitrate
Sodium
Sodium aluminate
Sodium anthraquinone sulfate
Sodium arsenate
Sodium arsenite
Sodium azide
Sodium bisulfite
Sodium borohydride
Sodium carbonate
Sodium chlorate
Sodium chloride
Sodium chromate
Sodium cyanide
Sodium dichromate
Sodium fluoride
Sodium fluoroacetate
Sodium fluorosilicate
Sodium hydrosulfide
Sodium hydrosulfite
Sodium hydroxide
Sodium hypochlorite
Sodium nitrate
Sodium nitrilotriacetic acid
Sodium phosphate
Sodium phosphate, tribasic
Sodium selenite
Sodium silicate
Sodium sulfate
Sodium sulfite
Sodium thioglycolate
Stannic chloride
Stannous chloride
Strychnine
Strychnine sulfate
Styrene
Sulfamic acid
Sulfotepp
Sulfur
Sulfur chloride
Sulfur dioxide
Sulfuric acid
Sulfuryl chloride
Temephos
Terephthalic acid
Terphenyl
Tetraethyl lead
Tetraethyl pyrophosphate
Tetrahydronaphthalene
Tetramethyl lead
Thallium
Thallium acetate
Thallium sulfate
Thioglycolic acid
Thionyl chloride
Thiosemicarbazide
Thiourea
Thiram
Titanium dioxide
Toluene
Toluene-2,4-diamine
Toluene-2,4-diisocyanate
Toluidine
Toxaphene
Tributyl phosphate
Trichlorobenzene
Trichloroethane
Trichloroethylene
Trichlorofon
Trichlorophenol
Trichlorophenoxy propionic acid
Tridecyl alcohol
Triethanolamine
Triethylamine
Trifluralin
Trimethylamine
Trimethylene bromide
Trinitrotoluene
Turpentine
Uranyl nitrate
Urea
Valeraldehyde
Vanadium pentoxide
Vinyl acetate
Vinyl chloride
Warfarin
Xylene
Xylenol
Yellow cake

THE TOP FIVE HUNDRED PRIORITY MATERIALS ctd.

Zinc acetate
Zinc bromide
Zinc chloride
Zinc cyanide
Zinc oxide
Zinc phosphate
Zinc sulfate
1,1-Dichloropropane
1,2,4,5-Tetrachlorobenzene
2,2'-Thiobis(4,6-dichlorophenol)
2,3,4,6-Tetrachlorophenol
2,3-Dibromo-1-propanol phosphate
2,4,5-Trichlorophenoxyacetic . (2,4,5-T)
2,4-Dichlorophenol
2,4-dichlorophenoxyacetic acid (2,4-D)
2,4-Dinitrophenol
2,4-Dinitrotoluene
2-Phenylphenol
4-Aminopyridine
5-[Bis(2-chloroethyl)amino] uracil

TABLE A3 ANALYSIS OF THE TOP 500 SPILL PRIORITY MATERIALS

CHEMICAL	RANK	SPILL NUMBERS	SPILL VOLUME (t)	SUPPLY VOLUME (t)
Ammonia	1	107	470	3700
Chlorine	2	36	120	1700
Tetraethyl lead	3	4	72	26
Styrene	4	24	5000	630
PCBs	5	334	89	
Sulfuric acid	6	155	13000	3700
Sodium cyanide	7	3	83	12
Hydrochloric acid	8	123	3300	170
Potassium chloride	9	31	12000	
Pentachlorophenol	10	19	110	1.5
Phenol	11	10	14	68
Zinc sulfate	12	3	68	1500
Phosphorus	13	16	46	68
Toluene	14	13	110	430
Copper sulfate	15	5	23	24
Sodium chloride	16	12	1400	12000
Calcium chloride	17	20	3700	340
Sodium hydroxide	18	92	8200	1800
Sodium chlorate	19	23	7700	440
Ammonium sulfate	20	8	260	330
Ammonium hydroxide	21	15	130	
Benzene	22	12	14	740
Xylene	23	14	47	290
Calcium hypochlorite	24	4	17	7.9
Formaldehyde	25	10	41	130
Acetic acid	26	9	73	71
Methyl alcohol	27	18	740	
2,4-dichlorophenoxyacetic acid (2,4-D)	28	37	130	3
Ethylene dichloride	29	1	780	820
Ammonium nitrate	30	63	4200	910
Sulfur	31	68	70000	7400
Sodium carbonate	32	3	25	570
Ammonium phosphates	33	5	140	1400
Propylene oxide	34	2	22	61
Perchloroethylene	35	10	15	27
Calcium hydroxide	36	17	360	2600
Nonylphenol	37	2	8.8	7
Ethylbenzene	38	4	0.79	730
Ethylene glycol	39	31	590	410
Fenitrothion	40	49	100	
Aminocarb	41	12	55	
Carbon tetrachloride	42	1	1.8	26
Vinyl acetate	43	8	7.4	44
Sulfur dioxide	44	16	90	140

TABLE A3 ANALYSIS OF THE TOP 500 SPILL PRIORITY MATERIALS

CHEMICAL	RANK	SPILL NUMBERS	SPILL VOLUME (t)	SUPPLY VOLUME (t)
Nitric acid	45	48	140	890
Phosphamidon	46	8	16	
Aldrin	47	2	1.3	
Phosphoric acid	48	12	37	520
Ferric chloride	49	8	1000	
Ethylhexanol	50	1	100	
Hydrofluoric acid	51	5	0.68	77
Toluene-2,4-diisocyanate	52	7	2	
Ethyl alcohol	53	3	51	
Carbaryl	54	2	70	
Parathion	55	1	0.01	
Calcium oxide	56	12	530	2600
MCPA	57	5	0.91	
Methylene chloride	58	4	6.2	10
Paraquat	59	2	44	
Hydrazine	60	3	4.5	
Malathion	61	7	0.29	
Sodium silicate	62	1	3.8	120
Acrylonitrile	63	1	4.6	16
Trichloroethane	64	4	0.81	
Hexane	65	5	8	
Zinc oxide	66	3	55	47
Isopropyl alcohol	67	4	9	
Chlordane	68	2	0.003	
Potassium cyanide	69	1	0.005	
Potassium permanganate	70	4	9.8	
Vinyl chloride	71	31	180	440
2,4,5-Trichlorophenoxyacetic acid (2,4,	72	2	0.24	
Dimethylamine	73	4	33	
Methyl methacrylate	74	3	3.4	18
Dieldrin	75	1	0.004	
Diazinon	76	4	0.3	
Acetone	77	4	9.9	23
Trichlorofon	78	3	2.6	
Naphthalene	79	3	6.4	
Ethylene	80	2	180	2200
Maleic anhydride	81	1	2.8	15
Dinoseb	82	1	0.91	
Calcium cyanide	83	1	0.09	
Methyl chloride	84	2	2.5	4.1
Benzoic acid	85	2	34	28
Chromic acid	86	8	8.8	2.8
Mercury	87	11	20	
Aniline	88	1	0.1	0.62

TABLE A3 ANALYSIS OF THE TOP 500 SPILL PRIORITY MATERIALS

CHEMICAL	RANK	SPILL NUMBERS	SPILL VOLUME (t)	SUPPLY VOLUME (t)
Oxygen (liquefied)	89	5	24	2700
Aluminum sulfate	90	9	120	220
Azinphosmethyl	91	1	0	
Hydrogen peroxide	92	7	0.71	34
Sodium hypochlorite	93	11	58	170
Ammonium chloride	94	1	0.7	2.7
Cresol	95	2	13	
Cyclohexane	96	1	0.11	60
Dichlorvos	97	1	0.1	
Calcium phosphate	98	3	100	160
Thallium sulfate	99	1	0.03	
Butyl alcohol	100	1	2	
Trinitrotoluene	101	1	17	
Potassium hydroxide	102	2	1.2	12
Phthalic anhydride	103	3	7.2	34
Benzene hexachloride (Lindane)	104	1	0.0009	
Zinc cyanide	105	1	0.2	
Zinc chloride	106	1	13	
Acetic anhydride	107	8	1.5	
Methyl ethyl ketone	108	4	7.7	12
Pyridine	109	2	0.005	
Trichloroethylene	110	1	0.13	3
Cobaltous nitrate	111	1	0.9	
Picloram	112	3	0.53	
Diethylamine	113	2	1.8	
Trifluralin	114	9	4.6	
Dicamba	115	2	0.17	
Atrazine	116	2	0.85	
Methoxychlor	117	1	0.05	
Nitrogen (liquefied)	118	3	1.8	340
Propylene glycol	119	1	8.3	19
Diquat	120	2	0	
Chlorophenol	121	1	0.04	
Sodium fluoride	122	1	0.2	
Benzotrifluoride	123	1	50	
Carbofuran	124	4	0.06	
Methylamine	125	1	5.3	6.3
Ethyl chloride	126	2	0.2	15
Sodium sulfite	127	4	29	16
Diphenyl ether	128	1	1.5	
Dinitramine	129	2	0.007	
Maneb	130	1	1.3	
Diethanolamine	131	1	0.2	
Tributyl phosphate	132	1	0.3	

TABLE A3 ANALYSIS OF THE TOP 500 SPILL PRIORITY MATERIALS				
CHEMICAL	RANK	SPILL NUMBERS	SPILL VOLUME (t)	SUPPLY VOLUME (t)
Titanium dioxide	133	2	0.5	110
Bromoform	134	1	0.014	
Terephthalic acid	135	1	0.18	45
Lignin sulfonate	136	5	180	
Propylene	137	1	9.1	660
Uranyl nitrate	138	3	0.21	
Nitroaniline	139	1	0.001	
Sodium hydrosulfite	140	2	29	8.4
Toluene-2,4-diamine	141	2	11	
Ethylene oxide	142			370
Acetylene	143	1	0.013	5.3
Lead oxide	144	2	2.1	34
Formic acid	145	1	0.2	
Endrin	146			
Propionic acid	147	1	2	
Zinc phosphate	148	1	0.9	
Thioglycolic acid	149	1	0	
Copper cyanide	150	1	2.2	
Isodrin	151			
Diallate	152	3	0.08	
Ethyl acrylate	153	3	1.1	
Asbestos	154	15	310	
Mercuric chloride	155			
Cesium 137	156	3	0.000003	
Cumene	157			45
Carbon dioxide	158	1	0	2500
Chlorine dioxide	159	2	0.3	
Fonofos	160			2500
Nitrogen dioxide	161	3	0.001	
Endosulfan	162			
Aldicarb	163			
Calcium carbide	164	1	1.8	82
Potassium carbonate	165	1	100	
Tetraethyl pyrophosphate	166			
Azinphos ethyl	167			
Ethyl mercaptan	168	6	0.01	
Calcium arsenate	169	1	0.045	
Demeton	170			
Nickel carbonyl	171	1	0.3	
Sodium nitrate	172	1	2.5	
Calcium nitrate	173	1	1.8	
Toxaphene	174			
Chlorohydrin	175	1	0.8	
Aluminum chloride	176			14

TABLE A3 ANALYSIS OF THE TOP 500 SPILL PRIORITY MATERIALS				
		SPILL	SPILL	SUPPLY
CHEMICAL	RANK	NUMBERS	VOLUME (t)	VOLUME (t)
Phenyl mercuric acetate	177	1	0.005	
Strychnine	178			
Cyanogen bromide	179	1	0.00005	
Carbon disulfide	180			21
Methoxyethylmercuric acetate	181			
Sodium dichromate	182			
Cycloheximide	183			
DDT	184			
Magnesium hydroxide	185	1	11	15
Hydrocyanic acid	186			
Sodium aluminate	187	1	14	9
Flamprop-methyl	188	3	0.16	
Triethanolamine	189	1	0.19	
Chloroform	190			3.7
Disulfoton	191			
Chlorpyrifos	192			
Sodium borohydride	193	1	4.5	17
Rotenone	194			
Chloroaniline	195	1	0.5	
Cyclohexylamine	196	1	0.07	
Cadmium	197			
Kepone	198			
Acetone cyanohydrin	199			
Acrolein	200			
Arsenic acid	201			
Borax	202			52
Ethion	203			
Mercuric acetate	204			
Mevinphos	205			
Cadmium sulfate	206			
Ethylamine	207	1	1.3	
Brucine	208			
Antimony trioxide	209			1500
Mercuric thiocyanate	210			
Ferric oxide	211	5	23	
Mercurous nitrate	212			
Methiocarb	213			
Acetaldehyde	214			8.5
Barium sulfate	215	1	820	
Methyl parathion	216			
Phosphorus pentoxide	217	1	0.6	
Dichlone	218			
Hexachlorophene	219			
Sodium chromate	220	1	0.02	

TABLE A3 ANALYSIS OF THE TOP 500 SPILL PRIORITY MATERIALS

CHEMICAL	RANK	SPILL NUMBERS	SPILL VOLUME (t)	SUPPLY VOLUME (t)
Thiram	221	1	0.3	
Butyl formate	222	1	0.04	
Copper chloride	223			
Sodium azide	224			
Sodium phosphate	225			65
Allyl alcohol	226			
Urea	227			2600
Coumaphos	228			
Nitrous oxide	229	1	0.6	
Sodium arsenite	230	1	0	
2,4-Dinitrophenol	213			
Dioxathion	232			
Propargyl alcohol	233			
Ferrous sulfate	234	1	21	
Hexachlorobutadiene	235			
Hydrogen sulfide	236			
Arsine	237	1	0	
2,3,4,6-Tetrachlorophenol	238			
Endothall	239			
Dinitrocresols	240			
Trimethylene bromide	241	1	0.4	
Dicrotophos	242			
Phenolsulfonic acid	243	2	23	
Diphenyl	244	1	1.3	
Glyphosate	245	1	0.003	
Heavy water	246	2	22	
Naled	247			
Hydroquinone	248			
Acrylamide	249			
Vanadium pentoxide	250			
4-Aminopyridine	251			
Ethanolamine	252			15
EPN	253			
Phosgene	254	1	0	
Phosphine	255	1	0.004	
Lactonitrile	256			
Malononitrile	257			
Mexacarbate	258			
Fluorine	259			
Fluoroacetamide	260			
Arsenic pentoxide	261			
Calcium fluoride	262	1	1	
Ethyleneimine	263			
Sodium hydrosulfide	264	2	2.3	

TABLE A3 ANALYSIS OF THE TOP 500 SPILL PRIORITY MATERIALS

CHEMICAL	RANK	SPILL NUMBERS	SPILL VOLUME (t)	SUPPLY VOLUME (t)
Aluminum phosphate	265	3	8.5	
Dimethyl ethyl amine	266	1	0	
Tetrahydronaphthalene	267	1	0.09	
Cadmium nitrate	268			
Lead arsenate	269			
Cobaltous chloride	270			
Cadmium chloride	271			
Phosmet	272			
Sulfur chloride	273	3	3.5	
Nicotine sulfate	274			
Boric acid	275			2
Sodium arsenate	276			
Copper acetate	277			
Nitrophenol	278			
Ferric hydroxide	279	2	5	
Hexachlorocyclopentadiene	280			
Sulfuryl chloride	281	2	4.4	
Crotonaldehyde	282			
Lead fluoroborate	283			
Morpholine	284			0.88
Stannous chloride	285			
Terphenyl	286	2	1.1	
Benzoyl chloride	287			
Thionyl chloride	288	1	53	
Trichlorophenoxy propionic acid	289			
Arsenic trioxide	290			
Barban	291	1	0.009	
Zinc acetate	292			
Copper nitrate	293			
Nonane	294	1	0.006	
Trichlorophenol	295			
Yellow cake	296	1	0.21	
Dibromomethane	297			
Dimethyl sulfate	298			
Hexachlorobenzene	299			
Dinitrobenzene	300			
Furfural	301			
Methyl ethyl ketone peroxide	302	1	0	
Stannic chloride	303	1	0	
2,3-Dibromo-1-propanol phosphate	304			
Xylenol	305			
Mercuric sulfide	306	1	30	
Adipic acid	307			72
Ethyl acetate	308			6.2

TABLE A3 ANALYSIS OF THE TOP 500 SPILL PRIORITY MATERIALS				
		SPILL	SPILL	SUPPLY
CHEMICAL	RANK	NUMBERS	VOLUME (t)	VOLUME (t)
Ethylene dibromide	309			
Nickel chloride	310			
Nitroglycerin	311			
Dodecylbenzenesulfonic acid	312			
Epichlorohydrin	313			
Methyl bromide	314			
Dimethoate	315			
Pyrocatechol	316			
2,4-Dichlorophenol	317			
Trichlorobenzene	318			
Decyl octyl phthalate	319	1	0.1	
Dibutyl amine	320			
Thallium acetate	321			
Sodium fluorosilicate	322			
Thiourea	323			
Benzyl chloride	324			
Temephos	325			
Dinitroaniline	326			
Maleic acid	327			
Quinone	328			
Sodium sulfate	329			410
Alachlor	330			
Calcium carbonate	331			250
Sodium nitrilotriacetic acid	332			
Tetramethyl lead	333			
Butylene	334			230
Glycidyl methacrylate	335			
Pentachlorobenzene	336			
Oleum	337			
Potassium sulfate	338			72
Butadiene	339			
2,4-Dinitrotoluene	340			
Chlorpropham	341			
Quinoline	342			
Hexachloroethane	343			
Arsenic	344			
Butyl mercaptan	345			
Propylene chlorohydrin	346	1	8.9	
Dichlorodifluoromethane	347			
N-Nitrosodiphenylamine	348			
Potassium dichromate	349			
Benzophenone	350			
Dichloroethyl ether	351			
Chlorobenzene	352			

TABLE A3 ANALYSIS OF THE TOP 500 SPILL PRIORITY MATERIALS

CHEMICAL	RANK	SPILL NUMBERS	SPILL VOLUME (t)	SUPPLY VOLUME (t)
2-Phenylphenol	353			
Allyl chloride	354			
Benzaldehyde	355			
Diuron	356			
Phenylenediamine	357	1	0	
1,2,4,5-Tetrachlorobenzene	358			
Adiponitrile	359			
Decyl alcohol	360			
Furfuryl alcohol	361			
Nitrosodimethylamine	362			
Nonanol	363			
Cobaltous hydroxide	364	1	5.1	
Magnesium oxide	365	1	5	
Resorcinol	366			
Sodium phosphate, tribasic	368			
Acetophenone	369			
Benzonitrile	370			
Chromous chloride	371			
Cobaltous bromide	372			
Diisopropylamine	373			
Hexanol	374			
Nitrobenzene	375			
Nitrotoluene	376			
Oleic acid	377			2.6
Tridecyl alcohol	378			
Trimethylamine	379	1	1.5	
Chlorodifluoromethane	380	1	0.22	
Methyl hexyl ketone	381	1	0.94	
Isobutyl acrylate	382			
Potassium aluminate	383	1	0.7	
Chloroethylvinyl ether	384			
Triethylamine	385			
Eptam	386			
Sodium	387	1	0.5	
Anthracene	388			
Butylamine	389			
Dimefox	390			
Iodomethane	391			
Phorate	392			
Sodium fluoroacetate	393			
Sulfotepp	394			
Zinc bromide	395	1	0.38	
Atlox	396	1	0.2	
Benzidine	397			

TABLE A3 ANALYSIS OF THE TOP 500 SPILL PRIORITY MATERIALS

CHEMICAL	RANK	SPILL NUMBERS	SPILL VOLUME (t)	SUPPLY VOLUME (t)
Sodium thioglycolate	398	1	0.2	
Lithium bromide	399	1	0.13	
Ammonium stearate	400	1	0.1	
Crimidine	401			
Isovaleraldehyde	402			
Caprolactam	403			12
Benzyl alcohol	404			
Methylstyrene	405			
Sodium bisulfite	406			
Dichlobenil	407			
Diphacinone	408			
Diphenylamine	409	1	0.03	
Fumaric acid	410			1.2
Oxalic acid	411			1.1
Nitralin	412			
Toluidine	413			
Warfarin	414			
Neopentyl glycol	415	1	0.01	
Benzyl-n-butyl phthalate	416			
Diethyl-p-nitrophenyl phosphate	417			
Furazolidone	418			
Carbonyl sulfide	419			
Dalapon	420			
N,N-Dimethylaniline	421			
Valeraldehyde	422			
Chlorophacinone	423			
Fensulfothion	424			
Methanesulfonyl fluoride	425			
Metobromuron	426			
Nitrilotriacetic acid	427			
Chloroxuron	428			
Diethyl-m-toluamide	430			
Methyl phenkapton	431			
Dimethylaniline	432	1	0.005	
Ammonium picrate	433			
Diphenylmethane-4,4'-diisocyanate	434			
Propionaldehyde	435			
Strychnine sulfate	436			
Isooctyl alcohol	437			
Methyl isobutyl ketone	438			8.7
Phenanthrene	439			
Hexaldehyde	440			
Hydrogen	441			1200
Phenylthiourea	442			

TABLE A3 ANALYSIS OF THE TOP 500 SPILL PRIORITY MATERIALS

CHEMICAL	RANK	SPILL NUMBERS	SPILL VOLUME (t)	SUPPLY VOLUME (t)
Amiton	443			
Beryllium	444			
Bromine	445			
Heptanol	446			
Nitropropane	447			
Octanol	448			
Sodium anthraquinone sulfate	449			
Glycerine	450			7.7
Silver nitrate	451			
Butyric acid	452			
Fluoranthene	453			
Naphthol	454			
Fluoroacetic acid	455			
Propionic anhydride	456			
Sulfamic acid	457			
Ammonium sulfamate	458			
Carboxymethylcellulose	459			2.5
Cyclohexanone	460			
Dibutyl ether	461			
Dithiobiuret	462			
Isobenzan	463			
Ethylene glycol monobutyl ether	464			
Butyraldehyde	465			0.2
Chromic sulfate	466			
Dimethyl phthalate	467			
Melamine	468			6.8
Fluenetil	469			
Nitromethane	470			
Choline chloride	471			5.8
Isophorone	472			
Naphtha	473			
Turpentine	474			11
1,1-Dichloropropane	475			
2,2'-Thiobis(4,6-dichlorophenol)	476			
Hexaethyl tetraphosphate	477			
Sodium selenite	478			
5-[Bis(2-chloroethyl)amino] uracil	479			
Camphor oil	480			
Dichloroethyl amino uracil	481			
Methyl amyl alcohol	482			
Monocrotophos	483			
Mephosfolan	484			
Thallium	485			
Chromium	486			

TABLE A3 ANALYSIS OF THE TOP 500 SPILL PRIORITY MATERIALS

CHEMICAL	RANK	SPILL NUMBERS	SPILL VOLUME (t)	SUPPLY VOLUME (t)
Ethylene thiourea	487			
Lead chloride	488			
Thiosemicarbazide	489			
Acetyl chloride	490			
Cantharidin	491			
Isobutyl alcohol	492			1.5
Propylamine	493			
Diethyl chlorophosphate	494			
Isopropylmethylpyrazolyl dimethylcarb	495			
Potassium chlorate	496			
Bisphenol A	497			1.9
Diethyl phthalate	498			
Salicylic acid	499			
Fluometuron	500			

LIST MEMBERSHIP COMPARISON

KEY
A=1990 Priority List Top 150 (x), 151-251 (y), 251-500 (z)
B=1981 Priority list
C=U.S. Coast Guard CHRIS List (1978)
D=EPA 129
E=EPA 65
F=U.S. Railroad Spill List
G=EPA Reportable Quantities List
H=U.S. Coast Guard Spill List
I=EPA Acutely Toxic or Potentially Dangerous Chemicals List (1986)
J=TDG Schedule 2
K=TDG Schedule 12
L=
M=U.S. Top 100
N=Spill History in Canada
O=AAR Hazardous Materials Data Base (1981)
P=SARA Section 302 Extremely Hazardous Substances (1987)
Q=CERCLA Hazardous Substances (1987)
R=SARA Section 313 Toxic Chemicals (1987)
S=RCRA Hazardous Wastes (1987)
T=CEPA Priority Substances List (1989)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Acenaphthene				x	x		x										x		
Acenaphthylene				x			x										x		
Acetaldehyde	y		x			x	x	x		x	x		x		x		x	x	x
Acetamide																		x	
Acetic acid	x	x	x			x	x	x		x			x	x	x		x		
Acetic anhydride	x	x	x			x	x	x		x			x	x	x		x		
Acetoacetanilide																			
Acetone	x	x	x			x		x		x			x	x	x		x	x	x
Acetone cyanohydrin	y		x				x		x	x	x		x			x	x		x
Acetone thiosemicarbazide									x							x			
Acetonitrile			x			x		x		x							x	x	x
Acetophenone	z		x														x		x
Acetyl bromide			x				x			x							x		
Acetyl chloride	z		x				x	x		x	x						x		x
Acetyl peroxide			x							x									
Acetylacetone			x																
Acetylene	x	x	x							x	x			x					
Acrolein	y		x	x	x		x	x	x	x	x					x	x	x	x
Acrylamide	y		x						x	x						x	x	x	x
Acrylic acid			x			x		x		x			x				x	x	
Acryloyl chloride									x							x			
Acrylonitrile	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x
Adipic acid	z	x	x				x			x			x				x		
Adiponitrile	z		x					x	x	x			x			x			
Alachlor	z																		
Aldicarb	y								x							x	x		x
Aldrin	x		x	x	x		x		x	x				x		x	x	x	x
Alkyl benzenesulfonic acid			x																
Allyl alcohol			x				x	x	x	x						x	x		x
Allylamine									x							x			

Allyl bromide			x							x									
Allyl chloride	z		x				x			x							x	x	
Allyl chloroformate			x							x									
Allyltrichlorosilane			x							x									
Aluminum																		x	
Aluminum chloride	y	x	x							x									
Aluminum fluoride			x																
Aluminum hydroxide		x																	
Aluminum nitrate			x							x									
Aluminum oxide																		x	
Aluminum phosphate	z									x				x				x	
Aluminum sulfate	x	x	x				x	x		x			x	x			x		
2-Aminoanthraquinone																		x	
Aminocarb	x	x												x					
Aminoethylethanolamine			x																
1-Amino-2-methyl antheaquinone																			
4'-Amino propiophenone																			
Aminopterin									x							x			
Amiton	z								x							x			
Amitrole																	x	x	x
Ammonia	x	x	x			x	x	x	x	x	x		x	x	x	x	x	x	
Ammonium acetate			x				x			x							x		
Ammonium benzoate			x				x			x							x		
Ammonium bicarbonate			x				x			x							x		
Ammonium bisulfate										x									
Ammonium bisulfite							x			x							x		
Ammonium carbamate							x			x							x		
Ammonium carbonate			x				x			x							x		
Ammonium chlorate										x									
Ammonium chloride	x	x	x				x			x				x			x		
Ammonium chromate							x			x							x		
Ammonium citrate			x				x			x							x		
Ammonium dichromate			x				x			x							x		
Ammonium fluoride			x				x			x							x		
Ammonium fluoroborate							x			x							x		

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Ammonium formate			x																
Ammonium hydrogen fluoride			x				x			x							x		
Ammonium hydroxide	x		x				x	x		x				x			x		
Ammonium iodide			x																
Ammonium molybdate			x																
Ammonium nitrate	x	x	x							x	x		x	x	x			x	
Ammonium nitrate-phosphate mixture			x							x	x								
Ammonium nitrate-sulfate mixture			x							x	x								
Ammonium oleate			x																
Ammonium oxalate			x				x			x							x		
Ammonium pentaborate			x																
Ammonium pentachloride																			
Ammonium perchlorate			x							x									
Ammonium persulfate			x							x									
Ammonium phosphate dibasic	x	x	x											x					
Ammonium phosphate hemibasic	x	x	x											x					
Ammonium phosphate monobasic	x	x	x											x					
Ammonium picrate	x									x	x						x		x
Ammonium silicofluoride			x				x			x							x		
Ammonium stearate	x		x											x					
Ammonium sulfamate	x		x				x	x		x							x		
Ammonium sulfate	x	x	x										x	x				x	
Ammonium sulfide			x			x	x			x									
Ammonium sulfite			x				x			x									
Ammonium tertrate			x				x			x							x		
Ammonium thiocyanate			x				x			x							x		
Ammonium thiosulfate			x				x	x		x							x		

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Ammonium vanadate																	x			
Amyl acetate			x				x			x							x			
Amyl alcohol			x					x		x										
Amyl chloride			x							x										
Amyl mercaptan			x							x										
Amyl methyl ketone			x							x										
Amyl nitrate			x							x										
Amyltrichlorosilane			x							x										
Aniline	x		x			x	x	x	x	x			x	x	x	x	x	x	x	x
Anisidine										x								x		
Anisoyl chloride			x							x										
Anthracene	z		x	x			x										x	x		
Antimony				x	x		x			x							x	x		
Antimony pentachloride			x		x		x			x							x			
Antimony pentafluoride			x		x				x	x	x					x				
Antimony potassium tartrate			x		x		x			x							x			
Antimony tribromide					x		x			x							x			
Antimony trichloride			x		x		x			x							x			
Antimony trifluoride			x		x		x			x							x			
Antimony trioxide	y		x		x		x			x							x			
Antimycin A									x							x			x	
Arsenic	z			x	x					x							x	x	x	x
Arsenic acid	y		x		x	x				x							x		x	
Arsenic disulfide			x		x		x			x							x			
Arsenic pentoxide	z				x		x		x							x	x		x	
Arsenic trichloride			x		x		x			x						x	x			
Arsenic trioxide	z		x		x	x	x	x		x										
Arsenic trisulfide			x		x		x			x							x			
Arsine	y	x							x	x	x			x		x				
Asbestos	y			x	x					x				x			x	x		x
Asphalt			x							x										
Atlox	z													x						
Atrazine	x		x											x						
Azinphosethyl	y								x							x				
Azinphosmethyl	x		x						x	x	x			x		x	x			
Barban	z													x						
Barium										x								x	x	
Barium carbonate			x																	
Barium chlorate			x							x										
Barium chloride																				
Barium cyanide							x			x							x		x	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Barium nitrate			x							x									
Barium perchlorate			x							x									
Barium permanganate			x							x									
Barium peroxide			x							x									
Barium sulfate	y	x												x					
Benazolin																			
Bentonite																			
Benzaldehyde	z		x							x									
Benzamine																			
Benzene	x	x	x	x	x	x	x	x		x			x	x	x		x	x	x
Benzenearsonic acid									x								x		
Benzene hexachloride (BHC)	x		x	x	x		x		x					x		x	x	x	x
Benzene phosphorus dichloride			x							x									
Benzene phosphorus thiodichloride			x							x									
Benzenesulfonyl chloride									x							x	x		x
Benzidine	z			x	x					x							x	x	x
1,2-Benzisothiazolin-3-one 1,1-dioxide																			
Benzo[b]fluoranthene				x															
Benzo[ghi]perylene							x										x		
Benzo[k]fluoranthene																			
Benzoic acid	x	x	x				x			x				x			x		
Benzonitrile	z		x				x			x							x		
Benzophenone	z		x																
Benzoquinone							x			x							x	x	x
Benzotrichloride									x							x	x	x	x
Benzotrifluoride	x									x				x					
Benzoyl chloride	z		x			x	x			x							x	x	
Benzoyl peroxide			x							x	x							x	
Benzyl alcohol			x																
Benzyl bromide			x							x									
Benzyl-n-butyl phthalate	z		x	x													x	x	
Benzyl chloride	z		x			x	x	x	x	x						x	x	x	x
Benzyl chloroformate			x							x									
Benzyl cyanide									x							x			
Benzylamine			x																

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Benzyldimethyl-octadecyl-ammonium chloride			x																	
Benzyltrimethyl-ammonium chloride			x																	
Benz[a]-anthracene				x													x		x	
Benz[a]-acridine																				
Beryllium	z		x	x	x					x	x						x	x	x	
Beryllium chloride			x		x		x			x							x			
Beryllium fluoride			x		x		x			x							x			
Beryllium nitrate			x		x		x			x							x			
Beryllium oxide			x		x															
Beryllium sulfate			x		x															
Bismuth oxychloride			x																	
Bisphenol A	z		x										x							
Bisphenol A diglycidyl ether			x																	
Boric acid	z	x	x																	
Boron tribromide			x							x										
Boron trichloride			x						x	x	x					x				
Boron trifluoride									x	x	x					x				
Bromine	z		x						x	x	x					x				
Bromine pentafluoride			x							x	x									
Bromine trifluoride			x							x	x									
Bromoacetone										x							x		x	
Bromobenzene			x							x										
Bromochlorodifluoro-methane																				
Bromoform	x			x						x				x			x	x	x	
1-Bromo-4-phenoxy benzene																				
Bromotri-fluoromethane										x										
Bromoxynil																				
Brucine	y		x							x							x		x	
BTX																				
1,3-Butadiene	z	x	x						x	x	x		x		x	x		x		
Butane			x							x	x									
1,4-Butanediol			x										x							
1,4-Butenediol			x																	
Butyl acetate			x		x	x	x			x							x			
Butyl acrylate			x				x			x			x					x		
Butyl alcohol	x	x	x				x			x			x	x	x		x	x	x	
Butyl formate	y									x				x						
Butyl hydroperoxide			x							x										

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Butyl isovalerate									x							x			
Butyl mercaptan	z		x							x									
Butyl methacrylate			x							x									
Butyl peroxy-2-ethylhexanoate										x	x								
Butyl peroxypivalate										x	x								
Butyl phenol			x							x									
Butylamine	z		x				x	x		x							x		
Butylated hydroxytoluene																			
Butylene	z	x	x							x	x								
Butylene oxide			x							x								x	
Butyltrichlorosilane			x							x									
Butyraldehyde	z	x	x					x		x			x		x			x	
Butyric acid	z		x				x	x		x							x		
Cacodylic acid			x							x							x		
Cadmium	y			x	x												x	x	x
Cadmium acetate			x		x		x			x							x		
Cadmium bromide			x		x		x			x							x		
Cadmium chloride	z		x		x		x			x									
Cadmium fluoroborate			x		x														
Cadmium nitrate	z		x		x														
Cadmium oxide			x		x				x							x			
Cadmium sulfate	y		x		x														
Cadmium stearate					x				x							x			
Calcium arsenate	y		x				x		x	x				x		x	x		
Calcium carbide	y	x	x			x	x			x	x			x	x		x		
Calcium carbonate	z	x																	
Calcium chlorate			x							x									
Calcium chloride	x	x	x										x	x					
Calcium chromate			x				x			x									
Calcium cyanamide										x									
Calcium cyanide	x		x				x			x	x			x			x		
Calcium dodecylbenzenesulfonate			x				x			x									
Calcium fluoride	z		x											x					
Calcium formate																			
Calcium hydroxide	x	x	x					x						x					

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Calcium hypochlorite	x	x	x				x			x				x			x			
Calcium nitrate	y		x							x				x						
Calcium oxide	x	x	x							x			x	x						
Calcium peroxide			x							x										
Calcium phosphate	x	x	x											x						
Calcium phosphide			x							x	x									
Calcium propionate hydrate																				
Calcium resinate			x							x										
Calcium sulfate dihydrate																				
Camphene			x							x										
Camphor oil	z		x							x										
Cantharidin	z								x							x				
Caprolactam	z	x	x										x							
Caprylic acid																				
Captan			x				x			x							x	x		
Carbachol chloride									x							x				
Carbamidoselenic acid							x										x		x	
Carbaryl	x	x	x				x			x				x			x	x		
Carbofuran	x	x					x		x	x				x		x	x			
Carbolic oil			x																	
Carbon dioxide	y	x	x							x			x	x	x					
Carbon disulfide	y	x	x			x	x		x	x	x				x	x	x	x	x	
Carbon monoxide			x							x	x									
Carbon tetrachloride	x	x	x	x	x		x	x		x			x	x			x	x	x	
Carbophenothion									x											
Carboxy-methyl-cellulose	z																			
Carene			x																	
Catechol			x															x		
Cesium 137	y													x						
Cetyl alcohol																				
Charcoal			x							x										
Chloramben																		x		
Chlordane	x	x	x	x	x		x	x	x	x	x			x		x	x	x	x	
Chlorine	x	x	x			x	x	x	x	x	x		x	x	x					
Chlorine dioxide	y									x				x						
Chlorine trifluoride			x							x	x									
Chlormequat																				
Chloro-acetophenone			x							x								x		
Chloroacetic acid			x					x	x	x										

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Chloroacetyl chloride			x							x						x	x		x
Chloroaniline	y		x							x				x					
Chlorobenzene	z		x	x	x		x	x		x							x	x	x
Chloro benzoyl peroxide										x									
4-Chlorobutyronitrile			x																
p-Chloro-m-cresol				x						x							x		x
4-Chloro-2-cyclopentyl phenol																			
Chlorodibromomethane				x													x		
5-Chloro-2-(2,4-dichlorophenoxy)-phenol																			
Chlorodifluoroethane										x	x								
Chlorodifluoromethane	z		x							x				x					
2-Chloro-4,6-dinitrophenol																			
2-Chloroethyl vinyl ether	z			x													x		x
Chloroform	y	x	x	x	x		x	x	x	x						x	x	x	x
Chlorohydrin	y		x																
Chloromercuri dinitrophenol																			
Chloromercuriphenol																			
Chloromethyl methyl ether			x	x					x	x						x	x	x	x
1-(Chloromethyl)-4-nitrobenzene									x							x			
Chloronaphthalene				x	x												x		x
Chloronitrobenzene										x									
Chloro nitrophenol																			
Chloro nitrophenol, sodium salt																			
Chloropentafluoroethane										x									
Chlorophacinone	z								x					x		x			
m-Chlorophenol	x				x					x									
o-Chlorophenol	x			x	x					x							x		x
p-Chlorophenol	x		x		x					x									
Chlorophenol, potassium salt																			
(2-Chlorophenyl) thiourea																x	x		x
Chloro phenyl phenol																			
Chloropicrin			x							x	x								
Chloroprene										x								x	
3-Chloropropionitrile									x							x	x		x

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Chlorosulfonic acid			x				x			x	x						x			
Chlorothalonil																		x		
Chlorotoluidine			x							x										
Chlorotoluidine hydrochloride										x										
Chlorotri- fluoromethane										x										
Chloroxuron	z								x											
Chlorpropham	z																			
Chlorpyrifos	y						x			x							x			
Choline chloride	z																			
Chromic acetate							x			x							x			x
Chromic acid	x		x				x			x				x			x			x
Chromic sulfate	z						x			x				x						x
Chromium	z			x	x												x	x	x	x
Chromous chloride	z				x		x			x										x
Chromyl chloride			x		x															x
Citric acid			x																	
Coal tar																				
Cobalt									x							x		x		
Cobaltous acetate			x																	
Cobaltous bromide	z						x			x							x			
Cobaltous chloride	z		x																	
Cobaltous formate							x			x							x			
Cobaltous hydroxide	z													x						
Cobaltous nitrate	x		x											x						
Cobaltous sulfamate							x			x										
Cobaltous sulfate			x																	
Copper				x	x		x										x	x		
Copper acetate	z		x		x		x			x							x			
Copper acetoarsenite			x		x		x			x										
Copper arsenite			x		x					x										
Copper bromide			x		x															
Copper chloride	y		x		x		x			x							x			
Copper cyanide	x		x		x					x	x			x			x		x	
Copper fluoroborate			x		x															
Copper hydroxide					x															
Copper iodide			x		x															
Copper naphthenate			x		x															
Copper nitrate	z		x		x		x			x							x			
Copper oxalate			x		x		x			x							x			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Copper oxide					x									x					
Copper sulfate	x	x	x		x		x	x		x				x			x		
Copper sulfate, ammoniated					x		x			x									
Copper tartrate					x		x			x							x		
Coumafuryl									x							x			
Coumaphos	y		x				x		x	x	x					x	x		
Coumatetralyl									x							x			
p-Cresidine																		x	
Creosote, coal tar			x			x				x									
Cresols		x	x				x	x		x				x		x	x	x	x
Crimidine	z								x							x			
Crotonaldehyde	z		x				x		x	x						x	x		x
Cumene	y		x						x	x			x						
Cumene hydroperoxide			x							x									
Cupferron																		x	
Cupriethylene-diamine			x							x									
Cyanoacetic acid			x																
Cyanogen			x							x	x						x		x
Cyanogen bromide	y		x						x	x				x		x	x		x
Cyanogen chloride			x				x			x	x						x		x
Cyanogen iodide									x							x			
Cyanophos									x							x			
Cyanuric acid																			
Cyanuric fluoride									x							x			
Cyclohexane	x	x	x			x	x	x		x			x	x	x		x	x	x
Cyclohexanol			x										x						
Cyclohexanone	z		x							x							x		x
Cyclohexanone peroxide			x							x	x								
Cyclohexenyl-trichloro-silane			x							x									
Cycloheximide	y								x							x			
Cyclohexyl-amine	y		x						x	x				x		x			
Cyclopentane			x						x	x						x			
Cyclophosphamide																	x		x
Cyclopropene			x							x	x								
Cymene			x							x									
2,4-D		x	x				x	x		x				x			x	x	x
2,4-D esters			x				x			x							x		
Dalapon	z		x					x									x		
DDD			x	x			x										x		x
DDE				x													x		
DDT	y		x	x	x		x			x							x		x
Decaborane			x						x	x									
Decabromodiphenyl oxide																		x	
Decahydro-naphthalene			x							x									
Decaldehyde			x																
Decene			x																

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Decyl alcohol	z		x							x										
Decyl benzene			x																	
Decyl octyl phthalate	z													x						
Demeton	y		x						x											
Demeton-S-methyl									x							x				
Diacetone alcohol			x							x										
Diallate	y													x			x	x	x	
4,4'-Diaminodiphenyl ether										x								x		
Diamyl phthalate			x																	
Diazinon	x		x				x			x				x			x			
Diazomethane																		x		
Dibenzofuran																		x		
Dibenzo[a,h]anthracene				x													x		x	
1,2:7,8-Dibenzopyrene																	x		x	
1,2-Dibromo-3-chloropropane																	x	x	x	
Dibromomethane	z									x							x	x	x	
2,3-Dibromo-1-propanol phosphate																	x	x	x	
Dibutyl amine	z		x							x										
Dibutyl ether	z		x					x		x										
Dibutyl ketone			x																	
Dibutyl phthalate			x	x					x							x	x	x	x	x
Dibutyl phenol			x																	
Dicamba	x	x					x			x				x			x			
Dichlobenil	z						x			x							x			
Dichlone	y						x			x							x			
Dichlorobenzene		x	x	x	x		x			x							x	x	x	x
Dichlorobenzidine				x	x															x
Di(p-chlorobenzoyl)peroxide			x							x										
3,3'-Dichloro(1,1'-biphenyl)-4,4'-diamine																	x	x	x	
Dichlorobromomethane				x													x	x		
Dichlorobutene			x							x						x				
Dichlorodifluoroethane																				
Dichlorodifluoromethane	z		x	x						x							x		x	
1,1-Dichloroethane				x						x							x		x	
Dichloroethoxy methane																				
Dichloroethyl amino uracil	z																			
3-[p-Di(chloroethyl)amino]phenyl-L-alanine																	x		x	
Dichloro ethyl ether	z		x						x							x	x	x	x	
1,1-Dichloroethylene	z		x	x		x	x	x		x					x		x	x	x	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1,2-Dichloroethylene	x		x	x		x				x							x		x
Dichlorofluoromethane										x									
Dichloroisopropyl ether										x									
Dichloro methyl ether																x	x	x	x
Dichloromethyl ketone																			
2,4-Dichlorophenol			x	x	x												x	x	x
3,4-Dichlorophenyl isocyanate									x	x	x								
1,1-Dicloropropane			x				x			x							x		
1,2-Dichloropropane			x	x	x		x	x		x							x	x	x
1,3-Dichloropropane								x		x							x		
1,2-Dichloropropene			x	x	x		x			x									
1,3-Dichloropropene			x				x			x							x	x	x
Dichlorotetrafluoroethane										x									
4,4-Dichlorotrichloromethylbenzhydrol			x																
Dichlorvos	x						x		x	x				x		x	x	x	
Dicrotuphos	y								x							x			
Dicumyl peroxide										x									
Dicyclopentadiene			x							x									
Dieldrin	x		x	x			x			x				x			x		x
Diepoxybutane									x							x	x	x	x
Diethanolamine	x		x					x						x				x	
Diethanolamine lauryl sulfate			x																
Diethyl carbonate			x							x									
Diethyl chlorophosphate	x															x			
Diethyl methyl amine														x					
Diethyl phthalate			x	x													x	x	x
Diethyl sulfate										x						x			
Diethyl-m-toluamide	x																		
Diethyl-p-nitrophenyl phosphate	x																x		x
Diethylamine	x		x			x	x							x			x		
Diethylbenzene			x																
Diethylene glycol			x										x						

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Diethylene glycol dimethyl ether			X																	
Diethylene glycol monobutyl ether			X																	
Diethylene glycol monobutyl ether acetate			X																	
Diethylene glycol monoethyl ether			X																	
Diethylene glycol monoethyl ether acetate																				
Diethylene glycol monomethyl ether			X																	
Diethylene-triamine			X							X										
Diethylhexyl phosphoric acid			X																	
Diethylzinc			X																	
Difluoroethane			X							X										
Difluorophosphoric acid			X							X										
Diheptyl phthalate			X																	
1,2-Dihydro-3-methyl benz[j]aceanthrylene																	X		X	
Diisobutyl ketone			X							X										
Diisobutyl-carbinol			X																	
Diisobutylene			X							X										
Diisodecyl phthalate			X																	
Diisopropanol-amine			X																	
Diisopropyl-amine	X		X							X										
Diisopropylbenzene hydroperoxide			X							X										
Dimefox	X								X							X				
Dimethoate	X								X							X	X		X	
Dimethyl (4-methylthio) phenyl phosphate																				
Dimethyl-acetamide			X																	
3,3'-Dimethyl(1,1'-biphenyl)-4,4'-diamine																	X	X	X	
Dimethyl carbamoyl chloride										X							X	X	X	
Dimethyl ether		X	X							X	X									
Dimethyl ethyl amine	X													X						
Dimethyl formamide			X							X										
Dimethyl hydrazine			X						X	X	X					X	X	X	X	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Dimethyl phosphorochloidothioate									x										
Dimethyl phthalate	z			x					x							x	x	x	x
Dimethyl sulfate	z		x						x	x						x	x	x	x
Dimethyl sulfide			x						x	x						x			
Dimethyl sulfoxide			x																
Dimethyl terephthalate		x	x																
Dimethyl-p-phenylenediamine									x										
Dimethylamine	x		x				x	x		x	x			x			x		x
Dimethylaniline	z													x					
Dimethyldichlorosilane			x						x	x	x						x		
Dimethylhexane dihydroperoxide			x							x	x								
Dimethylphenethylamine																	x		
Dimethylpolysiloxane			x																
Dimethylzinc			x							x	x								
Dimetilan									x										
Dinitramine	x													x					
Dinitroaniline	z		x							x									
Dinitrobenzene	z		x				x			x	x						x		
Dinitrocresols	y		x	x					x	x						x	x	x	x
2,4-Dinitrophenol			x	x			x			x	x						x	x	x
2,6-Dinitrophenol							x			x	x						x		
2,4-Dinitrotoluene			x	x	x		x			x							x	x	x
2,6-Dinitrotoluene				x	x		x			x							x	x	x
3,4-Dinitrotoluene					x		x			x							x		
Dinoseb	x	x							x					x		x	x		x
Dinoterb									x							x			
Dioctyl adipate			x															x	
Dioctyl phthalate			x	x					x							x	x	x	x
Dioctyl sodium sulfosuccinate			x																
Dioxane			x							x							x	x	x
Dioxathion	y															x			
Dioxolane									x	x						x			
Dipentene			x							x									
Diphacinone	z								x							x			
Diphenyl	y													x					
Diphenyl ether	x		x											x					
Diphenylamine	z		x											x					
Diphenyldichlorosilane			x							x									
Diphenylguanidine																			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1,2-Diphenylhydrazine				x	x												x	x	x	
Diphenylmethane-4,4'-diisocyanate	z	x	x							x								x		
Dipropylamine			x							x							x		x	
Dipropylene glycol			x																	
Dipropylnitrosamine																	x	x	x	
Diquat	x						x			x				x			x			
Disodium arsenite																				
Disodium hexafluorosilicate																				
Disodium nitrilotriacetate acid	z		x																	
Disulfoton	y						x		x	x	x					x	x		x	
Dithiazanine iodide									x							x				
Dithiobiuret	z								x							x	x		x	
Dithiocarbamate	z									x	x									
Diuron							x			x							x			
Dodecene			x										x							
Dodecyl mercaptan																				
Dodecylbenzene			x					x												
Dodecylbenzenesulfonic acid	z						x			x										
Dodecyltrichlorosilane			x							x										
Dowtherm			x																	
Endosulfan	y			x	x		x		x	x						x	x		x	
Endothall	y																x		x	
Endothion									x							x				
Endrin	x		x	x	x		x		x	x						x	x		x	
Epichlorohydrin	z		x				x	x	x	x			x			x	x	x	x	
EPN	z								x							x				
Eptam	z																			
Ethane			x							x	x									
1,2-Ethanediylbiscarbamodithioc acid																	x		x	
Ethanethioamide																	x	x	x	
Ethanolamine	z	x	x							x			x							
Ethion	y						x	x	x	x	x					x	x			
Ethoxy triglycol			x																	
Ethoxydihydropyran			x																	
Ethoxyquin																				
Ethyl 4,4'-dichlorobenzilate																	x	x	x	
Ethyl acetate	z		x			x		x		x							x		x	
Ethyl acetoacetate			x																	
Ethyl acrylate	y		x			x		x		x				x	x		x	x	x	
Ethyl alcohol	x	x	x					x		x			x	x						
Ethyl butanol			x							x										

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Ethyl butyrate			x							x										
Ethyl chloride	x		x							x	x			x	x		x	x		
Ethyl chloroacetate			x							x										
Ethyl chloroformate			z							x								x		
Ethyl ether			x							x										
Ethyl formate			x							x										
Ethyl hexyl tallate			x																	
Ethyl lactate			x							x										
Ethyl mercaptan	y		x							x				x						
Ethyl methacrylate			x							x							x		x	
Ethyl methanesulfonate																	x		x	
Ethyl nitrite			x							x										
Ethyl phosphonothioic dichloride			x							x	x		x							
Ethyl phosphorodichloridate			x							x										
Ethyl silicate			x							x										
Ethyl thiocyanate									x											
Ethyl Toluene																				
Ethylaluminum dichloride			x							x										
Ethylaluminum sesquichloride			x							x										
Ethylamine	y		x				x	x		x	x			x			x			
Ethylbenzene	x	x	x	x	x	x	x	x		x			x	x			x	x		
Ethylbis(2-chloroethyl) amine									x							x				
Ethyl dichlorosilane			x							x	x									
Ethylene	x	x	x							x	x		x	x	x			x		
Ethylene chlorohydrin			x							x						x				
Ethylene cyanohydrin			x					x								x	x			
Ethylenediamine			x				x	x	x	x										
Ethylene dibromide	z	x	x				x			x							x	x	x	
Ethylene dichloride	x	x	x	x		x	x			x			x				x	x	x	
Ethylene fluorohydrin									x											x
Ethylene glycol	x	x	x					x					x	x				x		
Ethylene glycol diacetate			x																	
Ethylene glycol diethyl ether			x							x										
Ethylene glycol dimethyl ether			x																	
Ethylene glycol monobutyl ether	z		x							x										
Ethylene glycol monobutyl ether acetate			x																	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Ethylene glycol monoethyl ether			x				x			x								x		
Ethylene glycol monoethyl ether acetate			x							x										
Ethylene glycol monomethyl ether			x							x								x		
Ethylene oxide	x	x	x			x			x	x	x		x		x	x	x	x	x	
Ethylene tetrachloride																				
Ethylene thiourea	x																			
Ethylenediamine tetraacetic acid			x				x			x							x			
Ethyleneimine	x		x						x	x	x					x	x	x	x	
Ethylhexaldehyde			x																	
Ethylhexanol	x		x										x	x						
Ethylhexoic acid																				
Ethylhexylacrylate			x																	
Ethylidenenorbornene			x																	
Ethylmercuric phosphate									x							x				
Ethylphenyldichlorosilane			x							x										
Ethylpropylacrolein			x																	
Ethyltrichlorosilane			x							x										
Famphur																	x		x	
Fenitrothion	x	x							x					x		x				
Fensulfothion	x								x							x				
Ferric ammonium citrate			x				x			x							x			
Ferric ammonium oxalate			x				x			x							x			
Ferric chloride	x	x	x			x	x	x		x				x	x		x			
Ferric fluoride							x			x										
Ferric glycerophosphate			x																	
Ferric hydroxide	x													x						
Ferric nitrate			x				x			x										
Ferric oxide	y													x						
Ferric sulfate			x				x			x				x						
Ferrous ammonium sulfate			x				x			x										
Ferrous chloride			x				x			x							x			
Ferrous fluoroborate			x																	
Ferrous oxalate			x																	
Ferrous sulfate	y		x				x	x		x				x			x			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Flamprop-methyl	y													x						
Fluenetil									x							x				
Fluoboric acid										x				x						
Fluometuron	z																	x		
Fluoranthene	z			x	x		x													
Fluorene				x			x										x			
Fluorine	z		x						x	x	x					x	x		x	
Fluoroacetamide	z															x	x		x	
Fluoroacetic acid	z									x						x				
Fluoroacetyl chloride																x				
Fluorouracil																x				
Fluosilicic acid						x				x										
Fluosulfonic acid			x							x										
Fonophos	y								x							x				
Formaldehyde	x	x	x			x	x	x	x	x			x	x	x	x	x	x	x	
Formaldehyde cyanohydrin									x							x				
Formic acid	x	x	x				x			x							x		x	
Formothion									x											
Fumaric acid	z		x				x			x				x			x			
Furan									x	x										
Furazolidone	z																			
Furfural	z		x				x	x		x										
Furfuryl alcohol	z		x							x										
Gallic acid			x																	
Gas oil, cracked			x																	
Gasolines			x							x					x					
Glutamic acid																				
Glutaraldehyde solution			x																	
Glycerine	z		x					x					x							
Glycidyl methacrylate	z		x																	
Glycidylaldehyde																	x		x	
Glyoxal			x																	
Glyphosate	y													x						
Heavy water	y													x						
Heptachlor			x	x	x		x			x							x	x	x	
Heptachlor-epoxide				x													x			
Heptane			x							x										
Heptanol	z		x																	
Heptene			x							x										
Herbadox																				
Herban																				
Herbisan																				
Hexachloro-naphthalene									x							x		x		
Hexachloro-benzene	z			x						x							x	x	x	x
Hexachloro-butadiene	y			x	x					x								x		
Hexachlorocyclo-pentadiene	z		x	x	x		x		x	x						x	x	x	x	
Hexachloro-ethane	z			x						x							x	x	x	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Hexachlorophene	y						x			x							x		x	
Hexachloropropane																				
Hexadecyltrimethylammonium chloride			x																	
Hexaethyl tetraphosphate	z									x	x						x		x	
Hexaldehyde	z		x							x										
Hexamethylenediamine			x							x			x		x					
Hexamethylenetetramine			x																	
Hexamethyleneimine			x							x										
Hexamethylphosphoramide																		x		
Hexene	z	x	x					x		x			x	x						
Hexanol	z		x							x										
Hexene			x							x										
Hexylene glycol			x																	
Hydrazine	x	x	x						x	x	x			x		x	x	x	x	
Hydrochloric acid	x	x	x			x	x	x	x	x	x		x	x	x	x	x	x		
Hydrocyanic acid	y		x				x	x	x	x	x		x		x	x	x	x	x	
Hydrofluoric acid	x	x	x			x	x	x	x	x	x			x	x	x	x	x	x	
Hydrogen	z	x	x							x	x									
Hydrogen bromide			x							x	x									
Hydrogen peroxide	x	x	x			x		x	x	x	x			x	x	x				
Hydrogen selenide									x	x	x					x				
Hydrogen sulfide	y	x	x				x		x	x	x					x	x		x	
Hydroquinone	y		x						x	x						x		x		
Hydroxyacetic acid																				
Hydroxylamine sulfate			x							x										
Hydroxypropyl acrylate			x																	
Hydroxypropyl methacrylate			x																	
Indeno(1,2,3-cd)-pyrene																				
Iodine																				
Iodomethane	z															x	x	x	x	
Iridium 192														x						
Isoamyl acetate																				
Isoamyl alcohol			x																	
Isoamyl nitrate																				
Isobenzan	z								x											
Isobutane			x							x	x									
Isobutyl acetate			x			x				x							x			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Isobutyl acrylate	z									x									
Isobutyl alcohol	z		x							x							x		x
Isobutylamine			x			x				x							x		
Isobutylene			x							x	x		x						
Isobutyraldehyde										x								x	
Isobutyric acid			x							x							x		
Isobutyronitrile			x						x	x						x			
Isodecaldehyde			x																
Isodecyl acrylate			x																
Isodecyl alcohol			x																
Isodrin	y								x										
Isooctaldehyde			x																
Isooctyl alcohol	z		x																
Isopentane			x							x									
Isophorone	z		x	x	x												x		
Isophorone diisocyanate									x	x						x			
Isophthalic acid			x																
Isoprene			x				x			x							x		
Isopropanolamine			x																
Isopropanolamine dodecylbenzenesulfonate							x			x									
Isopropyl acetate			x							x									
Isopropyl alcohol	x	x	x						x	x			x	x	x			x	
Isopropyl chloroformate									x	x						x			
Isopropyl ether			x																
Isopropyl formate									x										
Isopropyl mercaptan			x							x									
Isopropyl percarbonate			x																
Isopropylamine			x							x									
Isopropylamine dodecylbenzenesulfonate			x																
Isopropylmethylpyrazoyl dimethylcarbamate	z															x			
Isovaleraldehyde	z		x																
Jet fuel, JP-1			x																
Jet fuel, JP-3			x																
Jet fuel, JP-4			x																
Jet fuel, JP-5			x																
Kelthane							x			x							x	x	
Kepone	y						x			x							x		x
Kerosene			x							x									

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Lactic acid			x																	
Lactonitrile	z								x							x				
Lauric acid																				
Lauroyl peroxide			x							x										
Lauryl alcohol			x																	
Lauryl mercaptan			x																	
Lead				x	x		x										x	x	x	
Lead acetate			x		x		x			x							x		x	
Lead arsenate	z		x		x		x			x							x			
Lead chloride	z				x		x			x							x			
Lead chromate		x			x															
Lead dioxide					x					x										
Lead fluoride			x		x		x			x							x			
Lead fluoroborate	z		x		x		x			x										
Lead iodide			x		x		x			x										
Lead nitrate			x		x		x			x										
Lead oxide	x	x	x		x					x				x						
Lead phosphate					x												x		x	
Lead stearate					x		x			x							x			
Lead sulfate					x		x			x							x			
Lead sulfide					x		x			x							x			
Lead tetraacetate			x		x															
Lead thiocyanate			x		x		x			x							x			
Lewisite									x							x				
Lignin sulfonate	x													x						
Lithium			x							x										
Lithium aluminum hydride			x							x										
Lithium bromide	z													x						
Lithium carbonate																				
Lithium chromate							x			x										
Lithium hydride			x						x	x						x				
Magnesium			x							x										
Magnesium chloride										x										
Magnesium hydroxide	y	x												x						
Magnesium oxide	z													x						
Magnesium perchlorate			x							x										
Magnesium sulfate																				
Malathion	x	x	x				x	x		x				x			x			
Maleic acid	z		x				x	x		x							x			
Maleic anhydride	x	x	x				x	x		x			x				x	x	x	
Maleic hydrazide			x														x		x	
Malononitrile	z								x	x						x	x		x	
Maneb	x									x				x						
Mannitol										x										
MCPA	x	x												x						

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
MCPB																			
Melamine	z																	x	
Mephosfolan	z								x							x			
Mercaptobenzo-thiazole																			
Mercaptodi-methur							x			x									
Mercuric acetate	y		x		x				x	x						x			
Mercuric ammonium chloride			x		x					x									
Mercuric chloride	y		x		x				x	x						x			
Mercuric cyanide			x		x		x			x	x						x		
Mercuric iodide			x		x					x									
Mercuric nitrate			x		x		x			x									
Mercuric oxide			x		x				x	x									
Mercuric sulfate					x		x			x							x		
Mercuric sulfide	z		x		x									x					
Mercuric thiocyanate	y				x		x			x									
Mercurous chloride			x		x														
Mercurous nitrate	y		x		x		x			x							x		
Mercury	x	x	x	x	x					x				x			x	x	x
Mercury fulminate					x		x			x							x		x
Mesityl oxide			x							x									
Mesitylene									x							x			
Methacrylamide																			
Methyacrylic-anhydride									x							x			
Methacrylo-nitrile									x							x	x		x
Methacryloyl chloride									x										
Methallyl chloride			x							x									
Methane			x							x	x								
Methanesulfonyl fluoride	z															x			
Methidathion									x							x			
Methiocarb	y								x							x	x		
Methionine																			
Methoxychlor	x		x				x			x				x			x	x	x
Methoxyethylmercuric acetate									x							x			
Methyl 2-chloro-acrylate	y								x							x			
Methyl acetate			x							x									
Methyl acetylene-propadiene mixture			x							x	x								
Methyl acrylate			x					x		x								x	
Methyl alcohol	x	x	x			x		x	x	x			x	x	x		x	x	x

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Methyl amyl acetate			x							x										
Methyl amyl alcohol	z		x																	
2-Methyl benzenamine hydrochloride																				
Methyl bromide	z		x	x					x	x	x					x	x	x	x	
Methyl butyl ether										x								x		
Methyl butyl ketone			x																	
Methyl chloride	x		x	x		x	x	x		x	x		x	x	x		x	x	x	
Methyl chloroformate			x						x	x						x	x		x	
Methyl disulfide									x							x				
Methyl ethyl ketone	x	x	x			x		x		x			x	x	x		x	x	x	
Methyl ethyl ketone peroxide	z									x	x			x			x		x	
Methyl ethyl phenol methyl carbamate																				
Methyl ethyl pyridine			x							x										
Methyl formate			x							x										
Methyl hexyl ketone	x													x						
Methyl hydrazine			x						x	x						x	x	x	x	
Methyl isobutyl carbinol			x							x										
Methyl isobutyl ketone	z	x	x					x		x							x	x	x	
Methyl isocyanate									x	x						x	x	x	x	
Methyl isopropenyl ketone			x							x										
Methyl mercaptan			x				x		x	x	x					x	x		x	
Methyl methacrylate	x	x	x			x	x	x		x			x	x	x		x	x	x	x
Methyl parathion	y		x				x	x		x						x	x		x	
Methyl phenkapton	δ								x							x				
Methyl phosphonothioic dichloride			x						x	x										
Methyl salicylate																				
Methyl thiocyanate									x							x				
Methyl thiochlorosilane																				
Methyl vinyl ketone			x						x	x										
2-Methyl-5-vinyl pyridine									x							x				
Methylacetylene																				

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O		Q	R	S
Methylamine	x	x	x			x	x			x	x			x			x		
Methylaniline			x							x									
Methylcyclopentene			x							x									
Methylcyclopentadienyl manganese tricarbonyl			x																
Methyldichlorosilane			x							x	x								
Methylene chloride	x	x	x	x				x		x			x	x			x	x	x
4,4'-Methylene dianiline																		x	
1,2-Methylenedioxy-4-allyl benzene																			
1,2-Methylenedioxy-4-propenyl benzene																	x		x
1,2-Methylenedioxy-4-propyl benzene																	x		x
Methylethanolamine																			
Methylmercuric dicyanamide									x							x			
Methylpyrrolidone			x																
Methylstyrene	z		x																
Methylthiouracil																			
Methyltrichlorosilane			x						x	x									
Methomyl									x										
Metobromuron	z																		
Metolcarb									x							x			
Mevinphos	y						x		x	x	x					x	x		x
Mexacarbate	z						x		x	x						x	x		x
Mineral spirits			x																
Molybdenum trioxide			x															x	
Monocrotophos	z								x							x			
Morpholine	z	x	x							x									
MTBA																			
MTBE																			
Nabam			x																
Naled	y						x	x		x							x		
Naphtha	z	x	x			x				x									
Naphthalene	x		x	x	x		x	x		x			x	x			x	x	x
1,4-Naphthalenedione																	x		x
Naphthenic acids			x				x			x							x		
Naphthol	z																		
Naphthylamine			x							x							x	x	x
Natural gas		x	x							x	x								
Neohexane			x							x									
Neopentyl glycol	z													x					
Nickel				x	x				x							x	x	x	
Nickel acetate			x		x														
Nickel ammonium sulfate			x		x		x			x									
Nickel bromide			x		x														
Nickel carbonyl	y		x		x				x	x	x			x					

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Nickel chloride	z		x		x		x			x							x			x
Nickel cyanide			x		x					x							x		x	x
Nickel fluoroborate			x		x															x
Nickel formate			x		x															x
Nickel hydroxide					x		x			x										
Nickel nitrate			x		x		x			x										x
Nickel sulfate	z		x		x		x			x							x			x
Nicotine			x						x	x						x	x		x	
Nicotine sulfate			x						x	x						x				
Nitralin	z		x											x						
Nitric acid	x	x	x			x	x	x	x	x	x		x	x		x	x	x		
Nitric oxide			x						x	x	x									
Nitrilotriacetic acid	z	x	x															x		
Nitrites										x										
Nitroanilines	x		x							x				x						
Nitrobenzene	z		x	x	x		x	x	x	x			x			x	x	x	x	
Nitroethane			x							x										
Nitrofen																	x			
Nitrogen	x		x							x			x	x						
Nitrogen dioxide	y						x	x	x	x	x			x						
Nitrogen tetroxide			x							x	x									
Nitroglycerin	z	x								x							x	x	x	
Nitromethane	z		x							x										
Nitrophenols	z		x	x	x		x			x							x			
Nitropropane	z		x							x							x	x	x	
N-Nitrosodimethylamine	z			x	x				x								x	x		
p-Nitrosodiphenylamine	z				x												x	x		
Nitrosoguanidine										x	x									
Nitrosyl chloride			x							x	x									
Nitrotoluenes	z						x			x							x			
Nitrous oxide	y		x							x				x						
Nonane	z		x							x				x						
Nonanoic acid																				
Nonanal	z		x																	
Nonene			x										x							
Nonylphenol	x	x	x											x						
Norbormide									x							x				
Octachlornaphthalene																		x		
Octamethyl pyrophosphoramide																x	x		x	
Octane			x							x										
Octanol	z		x					x												
Octene			x																	
Octyl aldehyde										x										
Octyl epoxy tallate			x																	
Oils, croton			x																	
Oils, fuel; 2			x												x					
Oils, fuel; 6			x																	
Oleic acid	z		x																	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Oleum	x		x							x	x								
Oxalic acid	x		x																
1,2-Oxathiolane-2,2-dioxide																	x	x	x
10,10'-Oxydiphenoxarsine																x			
Oxydisulfoton									x							x			
Oxygen	x		x							x	x		x	x					
Paraldehyde										x							x		
Paraquat	x								x					x		x			
Paraquat dimethylsulfate																			
Parathion	x		x				x	x	x	x	x			x		x	x	x	x
PCBs	x	x	x	x	x		x	x		x				x			x	x	
Pentaborane			x						x	x									
Pentachlorobenzene	x						x										x		x
Pentachloroethane							x		x	x						x	x		x
Pentachloronitrobenzene																	x	x	x
Pentachlorophenol	x	x	x	x	x		x	x	x	x				x		x	x	x	x
Pentadecanol			x																
Pentadecylamine									x							x			
Pentaerythritol		x	x																
Pentane			x							x									
Pentene			x																
Peracetic acid			x						x	x						x		x	
Perchloric acid			x							x									
Perchloroethylene	x		x	x	x			x		x			x	x					
Perchloromethyl mercaptan			x						x	x						x	x		x
Petroleum naphtha			x							x									
Phenanthrene	x			x			x										x		
Phenol	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x
Phenolsulfonic acid	y													x					
Phenyl hydrazine hydrochloride			x						x							x			
Phenyl mercuric acetate	y						x		x	x				x		x	x		x
Phenyldichloroarsine			x						x	x						x	x		x
p-Phenylenediamine	x																	x	
2-Phenylphenol																		x	
Phenylsilatrane									x							x			
Phenylthiourea	x								x							x			
Phorate	x						x		x							x	x		x
Phosacetim									x							x	x		x
Phosfolan									x							x			
Phosgene	x		x			x	x		x	x	x		x	x		x	x	x	x
Phosmet	x								x							x			
Phosphamidon	x								x					x					
Phosphine	x								x	x	x			x		x	x		x

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Phosphoric acid	x	x	x			x	x	x		x			x	x	x		x	x		
Phosphorus	x	x	x			x	x	x	x	x			x	x		x	x	x		
Phosphorus oxychloride			x			x	x	x	x	x										
Phosphorus pentasulfide			x				x			x							x		x	
Phosphorus pentoxide	Y								x	x				x		x	x	x		
Phosphorus, red			x							x										
Phosphorus tribromide			x							x										
Phosphorus trichloride			x			x	x		x	x						x	x			
Phosphorus, white			x							x	x				x					
Phthalic acid																				
Phthalic anhydride	x	x	x							x			x	x			x	x	x	
Picloram	x													x						
2-Picoline										x							x		x	
Picric acid										x	x							x		
Piperazine			x							x										
Piperidine									x	x						x				
Polyaromatic hydrocarbons																				x
Polyphosphoric acid			x																	
Polypropylene			x																	
Potassium			x							x										
Potassium aluminate	x																			
Potassium arsenate			x				x	x		x										
Potassium arsenite							x		x	x										
Potassium binoxalate			x																	
Potassium bromate										x										
Potassium carbonate	Y													x						
Potassium chlorate	x		x							x										
Potassium chloride	x	x												x						
Potassium chromate			x				x	x		x							x			
Potassium cyanide	x		x				x	x	x	x	x			x		x	x		x	
Potassium dichloroisocyanurate			x							x										
Potassium dichromate	x		x				x			x							x			
Potassium fluoride										x										
Potassium hydroxide	x	x	x			x	x	x		x			x	x	x		x			
Potassium iodide			x																	
Potassium metabisulfite										x										

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Potassium nitrate						x				x					x				
Potassium oxalate			x																
Potassium permanganate	x		x			x	x	x		x				x			x		
Potassium peroxide			x							x									
Potassium phosphide										x	x								
Potassium silver cyanide									-							x	x		x
Potassium sorbate																			
Potassium sulfate	z	x																	
Promecarb									x							x			
Propane			x							x	x								
Propanolamine																			
Propargite							x			x							x		
Propargyl alcohol	y									x							x		x
Propargyl bromide									x							x			
Propiolactone			x						x							x		x	
Propionaldehyde	z		x							x								x	
Propionic acid	x		x				x	x		x				x			x		
Propionic anhydride	z		x				x			x							x		
Propionitrile									x	x						x	x		x
Propoxur																		x	
Propyl acetate			x							x									
Propyl alcohol			x					x		x									
Propyl chloroformate									x	x						x			
Propyl mercaptan			x							x									
Propylamine	z		x							x									
Propylene	x	x	x							x	x		x	x				x	
Propylene chlorohydrin	z									x				x					
Propylene glycol	x	x	x										x	x					
Propylene glycol methyl ether			x																
Propylene glycol, ally ether																x			
Propylene oxide	x	x	x			x	x	x	x	x	x		x	x	x	x	x	x	
Propyleneimine			x						x	x						x	x	x	x
Prothoate																x			
Pseudocumene																x	x		
Pyrene				x			x		x							x	x		
Pyrethrins							x			x						x			
Pyridine	x		x			x	x			x				x					
Pyrocatechol	z																		
Pyrogallic acid			x																
Quinoline	z		x				x			x							x	x	
Quinone	z																		
Resorcinol	z		x				x	x		x							x		x
Rotenone	y																		

	A	B	C	D	E	F	G	H	[illegible]	J	K	L	M	N	O	P	Q	R	S	T
Salicylic acid	z		x																	
Sarin									x							x				
Selenious acid							x		x							x	x		x	
Selenium				x	x		x													
Selenium dioxide			x				x										x		x	
Selenium disulfide										x							x		x	
Selenium oxychloride									x							x				
Selenium trioxide			x																	
Semicarbazide hydrochloride									x							x				
Silicon tetrachloride			x							x										
Silver				x	x												x	x	x	
Silver acetate			x		x															
Silver carbonate			x		x															
Silver fluoride			x		x															
Silver iodate			x		x															
Silver nitrate	z		x		x		x			x							x			
Silver oxide			x		x															
Silver sulfate			x		x															
Sodium	z		x				x	x		x				x	x		x			
Sodium acetate																				
Sodium aluminate	y	x								x				x						
Sodium amide			x							x										
Sodium anthraquinone sulfonate	z								x							x				
Sodium arsenate	z		x				x		x	x						x	x			
Sodium arsenite	y	x	x				x	x	x	x				x		x	x			
Sodium azide	y		x						x	x										
Sodium benzoate																				
Sodium bicarbonate																				
Sodium bifluoride							x			x										
Sodium bisulfate						x				x										
Sodium bisulfite	z	x	x			x	x			x							x			
Sodium borate	y	x	x																	
Sodium borohydride	y	x	x							x				x						
Sodium borohydrite																				
Sodium bromide																				
Sodium cacodylate			x						x	x						x				
Sodium carbonate	x	x											x	x						
Sodium chlorate	x	x	x							x			x	x	x					
Sodium chloride	x	x												x						
Sodium chlorite										x										
Sodium chromate	y		x				x			x				x			x			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Sodium cyanide	x	x	x			x	x	x	x	x	x			x		x	x		x	
Sodium dichloroisocyanurate			x							x										
Sodium dichromate	y	x	x				x	x		x										
Sodium ferrocyanide			x																	
Sodium fluoride	x		x				x			x				x			x			
Sodium fluoroacetate	z								x	x						x	x		x	
Sodium fluoroaluminate																				
Sodium fluorosilicate	z									x										
Sodium formate																				
Sodium hydride			x							x										
Sodium hydrosulfide	z		x				x	x		x	x			x						
Sodium hydrosulfite	x																			
Sodium hydroxide	x	x	x			x	x	x		x			x	x	x		x	x		
Sodium hypochlorite	x	x	x				x							x			x			
Sodium methanearsonate			x																	
Sodium methylate			x				x			x							x			
Sodium nitrate	y					x		x		x				x	x					
Sodium nitrite			x				x			x							x			
Sodium oxalate			x																	
Sodium pentachlorophenate									x	x						x				
Sodium perchlorate										x										
Sodium phosphate, dibasic	y	x	x				x	x		x							x			
Sodium phosphate, monobasic	y	x	x					x												
Sodium phosphate, tribasic	z	x	x				x	x		x							x			
Sodium phosphide										x	x									
Sodium selenite	z						x		x	x							x			
Sodium silicate	x	x	x										x	x						
Sodium sulfate	z	x											x					x		
Sodium sulfide			x					x		x										
Sodium sulfite	x	x	x											x						
Sodium thiocyanate			x																	
Sodium thioglycolate	z													x						

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
dium thiosulfate entahydrate																				
dium tripoly- osphate													x							
rbic acid																				
rbitol			x																	
nnic loride	z									x				x						
nnous loride	z									x										
rontium										x										
rontium romate							x			x										
rontium itrate										x										
rontium ulfide																	x			
rychnine	y						x	x	x	x	x					x	x		x	
rychnine ulfate	z								x	x	x					x				
yrene	x	x	x			x	x	x		x			x	x	x		x	x		x
yrene oxide																		x		
lfamic cid	z									x										
lfolane			x																	
lfotep	z								x							x	x		x	
lfur	x	x	x					x		x				x						
lfur loride	z		x				x	x		x				x						
lfur ioxide	x	x	x						x	x	x			x	x	x				
lfur tetra- uoride									x	x	x					x				
lfur rioxide									x	x	x					x				
lfuric acid	x	x	x			x	x	x	x	x	x		x	x	x	x	x	x		
lfuryl loride	z	x	x							x				x						
lfuryl uoride										x	x			x						
,5-T			x				x			x							x		x	
,5-T amines							x			x							x			
,5-T esters			x				x			x							x			
,5-T salts							x			x							x			
un									x							x				
l oil		x																		
nic acid			x																	
rteric acid																				
uthiuran																				
llurium exafluoride									x	x	x					x				
mephos	z																			
rephthalic cid	x	x											x	x				x		
rphenyl	z	x												x						
trabutyl itanate			x																	
2,4,5-Tetrachloro- enzene																	x		x	x
3,6,7-Tetrachloro- ibenzo-p- ioxin (TCDD)				x	x					x							x			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Tetrachloroethane	x		x	x						x							x	x	x	x
2,3,4,6-Tetrachlorophenol																	x		x	
Tetrachlorvinphos																		x		
Tetradecanol			x																	
Tetradecene			x																	
Tetradecylbenzene			x																	
Tetraethyl lead	x	x	x			x	x	x	x	x	x			x		x	x		x	
Tetraethyl pyrophosphate (TEPP)	y		x				x			x	x					x	x		x	
Tetraethylene glycol			x																	
Tetraethylenepentamine			x							x										
Tetraethytin																x				
Tetrafluoroethylene			x							x	x									
Tetrahydrofuran			x			x				x							x		x	
Tetrahydronaphthalene	z		x											x						
Tetramethyl lead	z		x						x							x				
Tetranitromethane										x	x					x	x		x	
Tetrasodium pyrophosphate																				
Thallic peroxide																				
Thallium	z			x	x		x			x							x	x		
Thallium acetate	z				x		x			x							x		x	
Thallium carbonate					x		x			x						x	x		x	
Thallium chloride					x		x			x						x	x		x	
Thallium nitrate					x		x			x										
Thallium peroxide					x		x			x						x	x		x	
Thallium selenide					x		x			x										
Thallium sulfate	z				x		x		x	x				x						
Thioglycolic acid	x								x					x						
Theometon									x							x				
Thioazin									x							x	x		x	
2,2'-Thiobis- (4,6-dichlorophenol)																x				
2,2'-Thiobis[4-chloro-6-methyl] phenol																x				
Thionyl chloride	z									x				x						
Thiophan sulfone																				
Thiophenol									x							x	x		x	
Thiophosgene			x							x	x									

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
hiosemi-carbazide	z								x							x	x		x	
hiourea	z									x										
hiram	y		x							x				x						
horium dioxide																		x		
horium nitrate			x							x										
hyroxine																				
itanium dioxide	x	x											x	x						
itanium tetrachloride			x							x						x		x		
oluene	x	x	x	x	x	x	x	x		x			x	x	x		x	x	x	x
oluene-2,4-diamine	x									x				x			x	x	x	
oluene-2,4-diisocyanate	x	x	x						x	x			x	x	x	x	x	x		
oluene-2,6-diisocyanate									x	x			x			x	x	x		
oluene-sulfonic acid			x							x										
oluidine	z		x				x			x										
olyl thiourea																				
oxaphene	y			x	x		x	x		x										
ri(2-butoxyethyl) phosphate																				
riallate		x																		
riamiphos									x							x				
ributyl phosphate	x													x						
richlorofon	x	x					x		x	x				x		x	x	x		
richloro-acetaldehyde																	x		x	
richloroacetyl chloride									x	x						x				
richloro-benzene	z		x	x						x							x	x		x
richloro-cyanuric acid																				
1,1-Tri-chloroethane	x	x	x	x				x		x			x	x						x
1,2-Tri-chloroethane	x		x	x				x						x			x	x	x	
richloroethyl mine																				
1,1-Tri-chloroethylene	x		x	x	x		x	x		x				x			x	x	x	x
richloro-luoromethane		x	x	x													x		x	
richloronate									x							x				
richloro-henol	z		x	x			x			x							x	x	x	
richlorophenoxy ropionic cid	z									x							x		x	
richlorophenyl ilane																x				
richloro-ilane			x							x	x									
richloro-s-riazinetrione			x							x										

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Trichlorotrifluoroethane																				
Tri-o-cresyl phosphate										x										
Tridecene			x																	
Tridecyl alcohol	z		x																	
Triethanolamine	y		x				x							x						
Triethoxysilane									x							x				
Triethylaluminum			x							x										
Triethylamine	z		x			x	x			x							x			
Triethylbenzene			x																	
Triethylene glycol			x																	
Triethylene tetramine			x							x										
Trifluorochloroethylene			x							x	x									
3-(Trifluoromethyl) benzenamine									x							x				
Trifluralin	x	x	x											x				x		
Triisobutylaluminum			x							x										
Trimellitic anhydride																				
Trimethylamine	z		x				x			x	x			x			x			
2,4,6-Trimethyl aniline									x							x				
Trimethylchlorosilane			x						x	x						x				
Trimethylene bromide	y													x						
Trimethylene chloride																				
Trinitrobenzene							x			x	x						x		x	
Trinitrotoluene	x	x								x	x			x						
Triphenyltin chloride									x							x				
Tripropylene glycol			x																	
Tris(1-aziridinyl) phosphine oxide			x																	
Trisodium nitrilotriacetate			x																	
Turpentine	z	x	x					x		x										
Undecanol			x																	
Undecylbenzene			x																	
Uranium dioxide	z	x												x						
Uranium hexafluoride										x	x									
Uranyl acetate			x				x			x							x			
Uranyl nitrate	x		x				x			x				x						
Uranyl sulfate			x																	
Urea	y	x	x										x							

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
rea peroxide			x							x										
rethan																				
aleraldehyde	z		x							x										
anadium oxytrichloride			x							x										
anadium pentoxide	y		x				x		x	x						x	x		x	
anadyl sulfate			x				x			x										
inyl acetate	x	x	x			x	x	x	x	x			x	x	x	x	x	x		
inyl bromide											x						x			
inyl chloride	x	x	x	x	x	x				x	x		x	x	x		x	x	x	
inyl fluoride			x							x	x									
inyl methyl ether			x							x	x									
inyl styrene																				
inylnorbornene									x							x				
inyltrichlorosilane			x							x										
arfarin	z								x							x	x		x	
ylene	x	x	x			x	x	x		x			x	x	x					x
ylenol	z		x				x	x		x							x			
,6-Xylidine										x								x		
inc				x	x		x										x	x		
inc acetate	z		x		x		x			x							x			
inc ammonium hloride			x		x		x			x										
nc arsenate			x		x					x										
nc borate			x		x		x			x							x			
nc bromide	z		x		x		x			x				x			x			
nc carbonate					x		x			x							x			
nc chloride	x	x	x		x		x	x		x				x			x			
nc chromate			x		x															
nc cyanide	x				x		x			x				x			x		x	
nc fluoride					x		x			x							x			
nc fluoro- orate			x		x															
nc formate					x		x			x							x			
nc hydro- ulfite					x		x			x							x			
nc nitrate			x		x		x			x							x			
nc oxide	x	x			x									x						
nc phenol- ulfonate			x				x			x							x			
nc hosphate	x													x						
nc phosphide			x				x		x	x	x					x	x	x		
nc silico- luoride			x				x			x										
c stearate																				
c sulfate	x	x	x				x			x				x						
rconium cetate			x																	
rconium trate			x				x			x										
rconium ychloride			x																	
rconium potassium uoride							x			x										
rconium sulfate			x				x			x										
rconium trachloride							x			x										

A paper presented to the Seventh Annual Environment Canada - "Technical Seminar on Chemical Spills"

SPILL RESPONSE:

DEALING WITH REGULATORY AGENCIES

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CANADA
April 1990

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1.0 INTRODUCTION

Environmental offences have entered a new era. Penalties are no longer licences to pollute or part of the necessary cost of doing business. The commencement of legal actions is becoming less negotiable and penalties are now significant. Million dollar fines are becoming more common and in one instance, intentional offences under the B.C. Waste Management Act, the maximum fine is now $3 million. Corporate decision makers are no longer protected by the corporate veil. Most legislation now contemplates officer/director liability and, in some cases, agent liability. Where an offence is strict liability, the intention to commit the offence is not necessary and the only substantive defence is due diligence. Due diligence, as a concept, is now figuring in the business policies of enlightened companies. It is an expensive but absolutely necessary aspect of everyday and long-term corporate planning.

However, with respect to the risk and consequences of spills, if there are two words which may be even more important than "due diligence" they are "spill preparedness". Spill preparedness is much more than having a contingency plan. It involves identifying risks and knowing in advance the required actions and conduct pursuant to the relevant legislation.

This paper will explore in some detail the regulatory and legal aspects of spill response. The result should a more in depth appreciation of what it means to be prepared for a spill in order to react in a legally and environmentally responsible way.

The first section of this paper reviews the relevant Alberta, British Columbia, and federal Legislation. Where applicable, the discussion of the legislation is structured under the following categories:

jurisdiction and administrative authority

preventative measures

remedial measures

clean up orders/costs

investigations

offences

Legislation which contains provisions in one or more of these categories is reviewed. An exhaustive legislative search for all relevant provisions or most recent amendments has not been conducted. This review is not meant as a reference tool. The object of the review is to explain the regulatory regime and provide background material for discussions which follow.

Following the legislative review the paper addresses issues which are encountered in complying with the regulatory regime to which spills are subject.

Finally the paper will deal with the more practical and less theoretical aspects of spill response and dealing with regulatory agencies.

Any legal opinions which may be presented in this paper are those of the author and not Triton Environmental Consultants Ltd.

2.0 OVERVIEW OF RELEVANT LEGISLATION AND REGULATIONS

2.1 General Comments

Jurisdiction

For the most part, the powers of regulatory authorities are confined to those set out within their enabling legislation. The scope and jurisdiction of legislation is defined by its provisions and often by its definitions. For example, an Act dealing with waste or hazardous chemicals will only regulate those substances falling with the definitions of waste or of hazardous chemicals.

Where there is something of significance to note about the jurisdiction, or limits on jurisdiction, of the legislation under discussion it will be dealt with under this heading.

Preventive Measures

Very often legislation covering a regulated activity which carries a risk to the environment will contain provisions requiring contingency plans, management plans, regular inspections, training or other measures aimed at preventing a spill. The legislation may or may not specifically designate that non-compliance with these requirements is on offence but non-compliance could reflect badly on any due diligence arguments in the event of a prosecution, or on sentencing in the court of a conviction.

The various preventative measures of the legislation reviewed should be considered collectively as providing examples of due diligence and spill preparedness measures which should be followed even in instances where they are not required by legislation.

Reporting

These provisions are extremely important and are apparently being strictly enforced. In the event of a spill immediate reporting to a specified authority is usually required. Often a subsequent written report is required. Where legislation contains immediate reporting provisions failure to comply with the provision is usually an offence. Where a spill is reported but the report was not immediate charges will usually result.

Required Remedial Measures

Where legislation specifies remedial measures to be taken in the event of a spill these matters are dealt with under this heading. Remedial action is usually required to be a immediate and it may be an offence to not take immediate remedial or clean up actions. Where inadequate remedial measures are taken regulatory authorities may have the power to take measures themselves and charge the costs back to the person or company responsible.

Clean Up Orders/Costs

Some legislation provides the power for orders to made directing that clean up or remedial actions be taken. These provisions are often aimed at ongoing management practices for polluting activities but where they either include or deal directly with spill situations they are dealt with under this heading. In conjunction with these provisions or independently, there may be provisions whereby the regulatory authority may undertake or contract out the remedial measures and charge the cost back to the person responsible spill.

Subsequent Investigations

Where a spill occurs the lead agency may want to conduct immediate or subsequent investigations to determine if charges should be laid and to collect evidence. Legislation may contain provisions which permit search and seizure. These provisions may also require cooperation and compliance with all reasonable requests for information. It is usually an offence to obstruct search and seizure activities or provide false information.

Offences & Penalties

Where legislation creates offences for matters relating to spills the offences and penalties are described under this heading. Examples are failure to report or take immediate remedial actions, obstructing an investigation, or the spill itself may be an offence by putting a person or company in violation of a permit or licence, or in breach of a non-polluting provision of an Act or regulation. These matters are not within the scope of this paper.

2.2 Alberta Legislation

2.2.1 Hazardous Chemicals Act, R.S.A. 1980, c. H-3
(as am. by S.A. 1982, c. 20; 1984, c. 50; and 1985, c. 30)

Jurisdiction and Administrative Authority

The regulatory regime under this Act, and the "Hazardous Waste Regulation," controls the handling and management of hazardous chemicals and hazardous waste for the protection of the environment. The definition of hazardous chemical is fairly broad; any substance that may constitute a danger to "the environment", "plant or animal life", or "human health".(s. 1)

The Act establishes a Hazardous Chemicals Advisory Committee which advises the Minister with respect to the content, administration, application, and enforcement of the legislation. (s. 5(4))

The Act's spill provisions are limited to spills occurring at facilities for the storage, treatment or disposal of hazardous chemicals. (s. 7.1(1)) "Facility" is not defined and neither is "treatment" of hazardous chemicals although it is defined with reference to hazardous waste. Spills during transportation on a highway are not within the jurisdiction of section 7.1.

The Act is administered by the Director of Pollution Control, Alberta Environment.

Preventative Measures

This Act contains no provisions requiring contingency plans or any other actions for the prevention of spills.

Reporting

There are no specific requirements in the Act for immediate reporting a spill.

Required Remedial Measures

Section 7.1 of the Act deals with required "Emergency Measures in the case of a Spill", but is restricted to spills at a "facility for the storage, treatment or disposal of the hazardous chemical". Immediately upon becoming aware of the spill the person responsible for the hazardous chemical must "take all reasonable emergency measures consistent with public safety to repair, remedy and confine the effects of and remove the hazardous chemical in such a manner as to effect maximum protection to human life, health and the environment".

Clean Up Orders/Costs

"Chemical Control Orders" are available to the Minister where hazardous chemicals threaten human health or safety or the environment.

The order is available in situations where "the use, handling, storage, sale, manufacture, disposal or display, or the method of application or of transportation of a hazardous chemical or of a substance or thing containing a hazardous chemical,"

> "(a) causes or is likely to cause impairment of the quality of the environment for any use that is being or is likely to be made of it,
> (b) causes or is likely to cause injury or damage to property or to plant or animal,
> (c) adversely affects or is likely to adversely affect the health or safety of any person,
> (d) impairs or is likely to impair the safety of any person, or
> (e) renders or is likely to render, directly or indirectly, any property or plant or animal life unfit for use by man" (s. 6 (1))

However, the actions the order may require are limited. The person responsible may be required to,

> -limit, control, or stop the rate of "application deposit, addition, emission or discharge into the environment"
>
> -comply with directions relating to "the manner in which a hazardous chemical may be handled, stored, used, disposed of, transported, displayed or manufactured." (s. 6 (2))

A chemical control order was issued to Byers Transport Ltd., after sodium chromate was spilled from one of its trucks onto highway 831 in Alberta. The order purported to require the Company to:

> "take all reasonable measures consistent with public safety to repair, remedy and confine the effects of and remove the hazardous chemical in such a manner as to effect maximum protection to human life, health and the environment" (Chemical Control Order issued to Byers Transport Limited, by A.R. Schultz, Director, Pollution Control Division, April 1, 1989).

It has been suggested that this order is outside the powers of the Director. It is argued that the provisions of section 6(2) contemplate continued direct control and management of the substance and are therefore not applicable in the event of an accidental spill. 1. However, the order is available where "handling" of the chemical meets any of the criteria specified in paragraphs (a) through (e) of section 6(1). It might also be argued that an order may be issued for the handling of spilled chemicals during clean up.

Subsections 7.1(3) and (4) of the Act do however provide for orders in the event of a spill at facilities for the storage, treatment, or disposal of hazardous chemicals. Where a spill occurs "the Director may take whatever action he considers necessary to protect human life or health or the environment, and may in wiring charge the cost of the action to any one or more of the persons responsible for the hazardous chemical." The cost is payable on demand and is recoverable by the Minister as a debt due to the Crown.

Footnote:

1. Alastair R. Lucas, "The Alberta Hazardous Waste Regulatory Framework." A paper presented to the Canadian Institue conference on "Western Canadian Hazardous Waste Management and Liability in the 1990's", Vancouver, B.C., September 1989.

Investigations

The Hazardous Chemicals Act, contains provisions for "Right of Entry" (s. 10), "Assistance to Inspectors" (s. 11), and "Search Warrants" (s. 12), which are applicable in the event of investigations related to a spill.

Pursuant to section 10 entry must be granted upon reasonable notice. Notice is not required where an inspection is pursuant to a chemical control order. Once entry is achieved, investigations and inspections may be carried out, tests conducted, and extracts of records may be examined, copied, or removed. Where entry is wrongfully refused a court order may be obtained and charges may also be laid under s. 11(3) and (2). Section 11 of the Act imposes a positive duty to assist the person conducting the inspection and furnish him with all required information.

Search warrants may be acquired for the purposed of obtaining items or documents which would afford evidence of a contravention of the Act. (s. 12(1))

In addition, to the entry, search and seizure provisions noted above, section 4(2) of the Act provides that the Minister may require production of any information the subject person or company may reasonably be expected to have on a chemical.

Offences and Penalties

A contravention of section 7.1 regarding required emergency measures in the event of a spill could result in a fine of up to $5,000. (s. 7.1(2)) There are no provisions for director/officer liability.

2.2.2 Transportation of Dangerous Goods Control Act, S.A. 1982, c. T-6.5,

"Transportation of Dangerous Goods Control Regulation", Alta. Reg. 383/85

Jurisdiction and Administrative Authority

The jurisdiction of this Act is integrated with that of the federal Transportation of Dangerous Goods Act. The jurisdiction of the provincial Act is limited to transportation by highway within Alberta. (s. 1 "transportation" and "vehicle") It does not apply to transportation by pipeline, aircraft, ships, and railways.

The regulations pursuant to the federal Act are extremely detailed and comprehensive and have been adopted by the Alberta regulation. (s. 3) The federal regulations define dangerous goods, and contain reporting requirements for spills.

The authority which administers this Act is Alberta Public Safety Services. The Disaster Services Division deals with spills on highways or during transportation by highway. They have a 24 hour toll free emergency number 1-800-272-9600, or in Edmonton, 422-9600. They utilize the Dangerous Goods Information System II which is a computer data base used to process information on spills.

In the event of a spill, Alberta Public Safety Services will usually be contacted by the police but sometimes they will be contacted directly by the consignor or person responsible for the spill. They, in term, will usually notify the Provincial Emergency Response Team (PERT) where the spill threatens the environment and remedial measures are required. An inspector may be dispatched or sent upon request to provide assistance or advice in the initial coordination of the response but this agency does not take part in the response. PERT, on the other hand, will usually send a representative to initiate, supervise, monitor or participate in the response.

Preventative Measures

A large part of this regulatory regime deals with preventative measures. There are provisions for labelling, packaging and training of drivers or other personal handling dangerous goods. The training procedures incorporate contingency plan measures.

Reporting

The Alberta Act requires that any spill or emission of dangerous goods must be reported as prescribed by the regulations. (s. 10(1)). The "regulations" are the adopted federal regulations, sections 9.13 and 9.14.

There must be immediate notification at the time of discovery. Notification must be made by either the person who had charge management or control of the dangerous goods (usually the driver of the truck), or by a person who is advised of the spill.(s. 9.13)

In Alberta the report is made to the local police. (Table II pursuant to s. 9.13 of the federal regulations)

The quantities which constitute a spill which must be reported are set out in Table I, pursuant to section 9.13 of the federal regulations. These quantities are related to the Class and Division system of the definition of dangerous goods in this regulatory regime.

Reporting, or notification must be immediate upon discovery of the spill. By way of example, in the case of the driver, nothing short of climbing a fence and running across a muddy field to the nearest phone qualifies as immediate unless it can put him in touch with the police any faster. The only exception is if there is some immediate action against the spill which can and should be taken, such as shovelling a dike to prevent contamination of a water system or putting out a fire with a fire extinguisher.

Within 30 days of the spill a full written report in the prescribed form is required. (s. 9.14)

Required Remedial Measures

Remedial measures are required of the same persons who are required to make a report under s. 10(1) of the Alberta Act. Such persons must take "all reasonable emergency measures consistent with public safety to repair or remedy any dangerous condition or reduce or mitigate any danger to life, health, property or the environment that results or may reasonably be expected to result from the discharge, emission or escape." (s. 10(2))

Clean Up Orders/Costs

Section 10 of the Alberta Act provides for clean up orders. If an inspector is satisfied that upon reasonable grounds a spill has occurred and that immediate action is required to "remedy any dangerous condition or to reduce or mitigate any danger to life, health, or property or the environment", he may request any qualified persons to take measures or may take them himself. This allows Alberta Environment to order persons responsible to conduct the clean up or they may arrange for, or conduct, the clean up themselves. Clean up costs may be charged to persons who through their fault or negligence caused or contributed to the spill. (s. 11)

Investigations

Where discharge of dangerous goods to the environment is occurring, or has occurred, or there is an imminent danger of such an occurrence, powers of search and seizure arise. (s. 8 the Act) These provisions are enforced by inspectors appointed by the Minister. (s. 6) Where an inspector considers it necessary for the prevention of any serious and imminent danger to life, health, property or the environment, he may seize and remove goods, vehicles or containers. (s. 8(2)) Inspectors a also have the power to enter and inspect a place or vehicle where dangerous goods are handled at any reasonable time without a permit for the purpose of ensuring compliance with the Act and regulations (s. 7). The grounds for entry, inspection, and seizure are specified but are broad enough to include spills. Upon inspection an inspector may also take samples of dangerous goods or remove documents which he has grounds to believe contain any information relevant to the administration and enforcement of the Act and regulation. (s. 7(3)) Subsections 7(4) and 7(5) provide that all reasonable assistance must be provided to the inspector. It is an offence to obstruct an inspector or to provide false or misleading information. The penalty is a maximum fine of $20,000 or one year imprisonment or both. (s. 7(5) and s. 20(2))

Where a spill results in death or injury to any person, danger to the health or safety of the public, or damage to property, the Minister may order a public inquiry. (s. 18(1))

Offences and Penalties

The penalty for failure to report a spill is prescribed by section 20(2) of the Act. The penalty is a maximum fine of $10,000, imprisonment for one year, or both.

Section 22 provides that an accused corporation may be found guilty for the acts of its employees whether or not they are also charged. However, as a defence, an accused corporation may try to establish that the offence was committed without its knowledge and that all reasonable steps were taken to prevent the commission of the offence. The general defence of due diligence has also been specified in section 21. It is provided that as a defence the accused may establish "that he took all reasonable measures to comply with this Act."

2.2.3 Pipeline Act, R.S.A. 1980, c. P-8
(as am. by S.A. 1981, c. B-15, c. 30; 1983, c. 0-5.5, c. 27, c. 37; 1984, c. 32; 1985, c. 46; and 1986, c. 15, c. D-20.5)

"Pipeline Regulation", Alta. Reg. 122/87
(as am. by Alta. Reg. 316/87)

Jurisdiction and Administrative Authority

This Act applies to all provincial pipelines as, defined in section 2 of the Act. Federal pipelines are governed by The National Energy Board and are beyond the jurisdiction of this Act. This Act is under the jurisdiction of the Energy Resources Conservation Board (ERCB), an independent administrative authority.

The Act contains provisions regarding spills which result from leaks or breaks in pipelines.

Preventative Measures

Most of the regulation is concerned with the enforcement of standards and safety requirements for the prevention of leaks and ruptures. The regulation requires operations manuals, emergency procedures manuals (in some cases), and regular inspections with records of inspections. (sections 49-53)

Reporting

The Act provides that, leaks and breaks must be immediately reported to the ERCB (s. 36(1)). Subsequent written reports maybe required where the leak or break occurred as a result of a ground disturbance (s. 36(2)). If a spill occurs on Crown land or in a forested area the location and quantity of the spill must also be reported immediately to the Department of Forestry, Lands and Wildlife. (s. 36(3))

Section 55 of the regulation provides for a report of the spill to be made in writing to the ERCB upon request.

Remedial Actions

The regulation provides that where a spill occurs from a leak or break in a pipeline, immediate steps must be taken to stop the spill at its source, contain it, and clean it up. (s. 54)

Clean Up/Costs

Where a spill occurs, and it appears to the ERCB that clean up may not occur in a timely manner, they may order clean up (s. 37(a)) or conduct the clean up themselves and recover costs. (s. 37(1)(b) and s. 37(3))

When the ERCB conducts a clean up, the persons responsible for the pipeline, and their employees, must work under the direction of the ERCB and obey any orders they give concerning the cleanup. (s. 37(2))

Investigations

There are no specific provisions concerning investigations, entry, search and seizure.

Offences and Penalties

Any contravention of the requirements of the Act or the regulation is an offence. (s. 51(2)) It is also an offence to obstruct an investigation or provide false information to a member of the ERCB. (s. 51(3) & (4))

Maximum fines are $10,000 for a corporation and $5,000 maximum for an individual.(s. 53(1) If the offence is continuing, each successive day the offence continues could raise the fine by $5,000 for a corporation and $2,500 for an individual. (s. 53(2)) Prison for up to 6 months may be imposed on a person in default of payment of the fine.

There is no provision for director/officer liability.

2.2.4 Agricultural Chemicals Act, R.S.A. 1980, c. A-6 (as am. S.A. 1984, c. 1)

This Act contains the following provision,

> "11. *Dumping prohibited.* Subject to the *Clean Air Act* and the *Clean Water Act*, every person who deposits, adds, emits or discharges an agricultural chemical or a substance or thing containing an agricultural chemical on or into the natural Environment in a manner not prescribed by the regulations or, if there are not regulations, in a manner not recommended by the manufacturer and thereby

> (a) causes or is likely to cause injury or damage to, impairment of, the quality of the natural environment, or
>
> (b) causes or is likely to cause injury or damage to plant or animal life,
>
> shall forthwith notify the Minister and shall take all measures that the Director by order may prescribe with respect to the cleaning and decontamination of the natural environment or any plant or animal life, substance or thing that has come into contact with an agricultural chemical by any means other than in accordance with this Act and the regulations or a licence, permit or order under this Act."

Although by the wording deposits, adds, emits, discharges, this provision appears to cover only intentional deposits and not unintentional deposits or spills, it requires reporting as if intentional spills were contemplated.

Inspectors appointed by the Minister may, for the purposes of carrying out the Act and the regulations,

> "(a) at any reasonable time enter on and inspect any land, premises, vehicle, equipment, record, document or other property.
>
> (b) inspect and take samples of or extracts from anything referred to in clause (a) or of any soil, water, food, feed, crop, animal agricultural chemical or other substance, and
>
> (c) subject anything referred to in clause (b) to laboratory analysis or other examination for the purpose of determining whether or not the article or substance in question is or has been contaminated by an agricultural chemical."
>
> (s. 22(1))

The inspector may be required to furnish his certificate of designation prior to entry if requested. (s. 22(3))

Upon conducting an inspection the inspector must be given all reasonable assistance. (s. 24)

2.3 British Columbia Legislation

2.3.1 Waste Management Act B.C., S.B.C. 1982, c. 41 (as am. by S.B.C. 1983, c. 10, c. 20; 1984, c. 25, 1985, c. 52; 1987, c. 51; and 1989, c. 62)

"Special Waste Regulations," B.C. Reg. 63/88

Jurisdiction and Administrative Authority

This Act deals with "Waste", "Special Waste", and "polluting substances". Administration of the Act was recently by the Waste Management Branch of the Ministry of Environment. However, the Ministry of Environment is currently reorganizing its administrative structure. The administration of this Act will probably fall within the jurisdiction of one or more of the branches or divisions of the new Environmental Protection Division.

The Act and regulations are enforced by Regional Waste Managers and Officers. Mangers are designated by the Minister and Officers are designated by the Director of Waste Management. (s. 1(1))

The jurisdiction of the "Special Waste Regulation" is restricted to "special waste" which is defined in s. 1(1) as follows,

> "(a) dangerous goods which are no longer used for their original purpose and that are:
>
> (i) recyclable materials, or
> (ii) that are intended for treatment or disposal, including storage before treatment or disposal, but does not include dangerous goods that are
> (iii) refuse that is collected by or on behalf of a municipality from residential premises,
> (iv) sewage,
> (v) defective or otherwise not usable for the intended purpose and that are in the process of being returned directly to the manufactures or supplier, or
> (vi) included in class 7 of the Federal Regulations,
> (vii) listed in List II of Schedule II of the Federal Regulations (Transportation of Dangerous Goods Act) and have the numeral 37 in Column IV of that list,

(b) waste oil,
(c) waste asbestos,
(d) waste pest control containers and wastes containing pest control products, and
(e) leachable waste"

Preventative Measures

Section 10 of the Act addresses preventative measures regarding spills of polluting substances. Polluting substances are defined as "any substances, whether gaseous, liquid or solid, that could, in the opinion of the Minister, substantially impair the usefulness of land, water or air if it were to escape into the air, or were spilled on or were to escape onto any land or into any body of water." s. 10(1)) Where the Minister considers it necessary to lessen the risk of an escape or spill of a polluting substance he may order that the person with possession, charge or control of the substance conduct a risk assessment, prepare a contingency plan, or carry out construction or other measures necessary to prevent or abate an escape or spill of the substance. (s. 10(2)) The Minister may also require that a contingency plan be tested. (s. 10(4))

The "Special Waste Regulation" contains further preventative measures. Most of the regulation deals with measures for safely disposing of, storing, and treating special waste. Facilities for the disposal, treatment and storage of special waste are subject to siting and operational requirements contained in Part 3. Section 10 of Part 3 provides that the owner of a facility shall provide and maintain an approved spill containment system. (s. 10(2)) The facility must either be inspected weekly or monthly if the facility has a 24 hour spill alarm system. (s. 10(b)). Records of inspections must be kept. (s. 10(c)) Spill protection systems must be tested at least once a year. (s. 12)

The owner of the facility must prepare and maintain in up-to-date readiness an approved contingency plan which provides for cleanup equipment and which documents procedures to be followed during emergencies. (s. 11) All persons employed by the facility must be given on the job training in spill response procedures. (s. 13).

Recycling facilities, short term storage facilities, treatment facilities, incinerators and thermal facilities, mobile facilities, secure landfills, waste piles and treatment ponds, and long term storage facilities, are all subject to specific preventative requirements in the Regulation.

Reporting

Where an unauthorized spill of a polluting substance occurs the person who had possession, charge or control of the substance or waste immediately before the spill must report in accordance with the regulations.(s. 10(5)) With the exception of a limited and specific provision in the "Special Waste Regulation" there are, as of yet, no regulations governing the reporting of spills. The reporting provision is therefore technically unenforceable. However, in practice it is recommended that the provision be treated as enforceable and reports made in compliance with its requirements.

A draft "Spill Reporting Regulation" dated April 6, 1980, has been prepared and distribution for comment was scheduled for the week of April 30, 1990. The draft regulation makes an ambitious attempt at the difficult task of comprehensively specifying in all situations what amounts to a reportable spill. This is done by way of a table of substances and reportable quantities. In categorizing substances the drafters have prudently maintained consistency with categories in the federal Transportation of Dangerous Goods Regulations, and other provincial legislation.

The Act provides that the report must be made "immediately" after a person "learns" of the spill. Establishing the point at which a person learns of a spill is often an issue. This Act deals with the matter by establishing what is known in law as a "reverse onus". The Act specifies that in a prosecution for failure to report, the accused is presumed to know of the spill and he carries the burden of proving otherwise. (s. 10(6)

Section 10 (d) of the "Special Waste Regulations" provides that "irregularities" at a special waste facility must be immediately reported to the director or a manager. Irregularities are not defined, but presumably they include spills.

Remedial Measures

The Act does not specify any remedial measures which must be taken in the event of a spill. The draft reporting regulation refers to remedial measures but this provision may be removed as there is some doubt as to whether there is jurisdiction in the regulation making powers under the Act for such provisions.

Clean Up Orders/Costs

Where a spill is causing pollution, a manager may order "the person who had possession, charge or control of the substance at the time of the spill, or any other person who caused, or authorized the pollution" to,

> "(a) provide to the Manager any information that the manager requests relating to the pollution,
> (b) undertake investigations, tests, surveys, and any other action the manager considers necessary to determine the extent and effects for the pollution and to report the results to the Manager,
> (c) acquire, construct, or carry out any works or measures that are reasonably necessary to control, abate or stop the pollution,
> (d) adjust, repair or alter any works to the extent reasonably necessary to control, abate or stop the pollution, and
> (e) abate the pollution" (s. 22 (1) and (2))

Where a contingency plan is in place, a manager may order that it be put into operation. (s. 10(3))

Investigations

Waste management officers may upon presentation of proof of identity enter on any works or land, that,

> "(a) produces or is capable of producing waste,
> (b) causes or is capable of causing pollution, or
> (c) is used for the storage, handling, treatment, destruction or disposal of waste" (s. 21(1))

The Act does not specify any grounds which must be satisfied in order for the entry powers to arise and presumably these powers could be exercised to investigate a spill.

The officer may examine and take away records relating to, the causing of pollution. (s. 21(2)(a)(i)) "Pollution" is defined as "the presence in the environment of substances or contaminants that substantially alter or impair the usefulness of the environment". (s. 1(1)) Inspections, measurements and tests may be carried out to ascertain the extent of the pollution. (s. 21(2)(b)) Where entry is refused, a search warrant may be obtained. (s. 21(3) and (4))

Offences

Contravention of provisions relating to the prevention and reporting of spills, and required remedial measures (s. 10) is an offence. The penalty is a maximum fine of $200,000. (s. 34(2)) Contravention of the provisions regarding investigations, or obstruction of investigations is also an offence for which there is the same maximum fine. (s. 34(4.1)) The penalty for contravention of orders made pursuant to the Act is a maximum fine of $300,000. (s. 34(8))

Where a corporation commits an offence under the Act, an employee, officer, director, or agent of the corporation who authorized, permitted, or acquiesced in the offence also commits the whether or not the corporation is convicted. (s. 34(10)

Where an offence is continuing, each new day constitutes a separate offence and carries with it liability for the maximum fine. (s. 34(13))

Where a person is subject to a monetary penalty specified in section 34 they are also liable to imprisonment for up to six months. (s. 34(16))

Where a person or corporation is convicted of an offence under this Act and they have derived monetary benefits from the commission of the offence, they may be subject to an additional fine equal to the amount of the monetary benefit. (s. 34.1)

Where damage or loss of use of the environment is intentional, or where a person shows wanton and reckless disregard for the lives or safety of other persons and thereby causing a risk of death or harm to other persons, the penalty is a maximum fine of $3,000,000, or imprisonment for up to 3 years or both. (s. 34.2)

2.3.2 Transport of Dangerous Goods Act, S.B.C. 1985, c. 17

"Transport of Dangerous Goods Regulation," B.C. Reg.203/85

Jurisdiction and Administrative Authority

The B.C. Act purports to establish a slightly broader jurisdiction than the Alberta Act. "Transportation" is defined to include transport by rail as well as by highway. The definition does not exclude railways extending beyond the province. The significance of this is that in the British North America Act, which establishes areas of jurisdiction as between the federal and provincial governments of Canada, it is specified that the provincial area of jurisdiction over local works and undertakings excludes railways "extending beyond the limits of the Province." (s. 92(10)).

The question of whether in any given situation a railway extends beyond the limits of a province is raised by the British Columbia jurisdictional approach but is beyond the scope of this paper.

The administration of the Act is divided between two Ministries. Road vehicles are regulated by the Motor Vehicle Inspection Branch of the Ministry of the Solicitor General. Rail vehicles are regulated by the Engineering and Inspection Branch of the Ministry of Municipal Affairs.

As with Alberta, the B.C. regulation also adopts the federal regulations. Where the provisions are the same in B.C. as they are in Alberta this will be pointed out and discussion of these provisions will not be repeated.

Section 6 of the Act provides for the appointment of inspectors by the Minister. (presumably by either of the two Ministers)

Preventative Measures

Other than the preventative measures contained in the Federal Regulations as adopted by the B.C. Regulations, the B.C. Act contains no further specific preventative measures.

Reporting

The Act specifies that the person who was in charge, management or control of the goods at the time of the spill must report in the manner and circumstances established by the regulations. (s. 21(1)). Sections 9.13 and 9.14 of the federal regulations are applicable and have been described in the section of the paper on the Alberta Act.

Required Remedial Measures

The Act requires that remedial actions be taken as soon as possible. The person who was required to make the report must take all reasonable emergency measures, consistent with public safety, to repair or remedy a dangerous condition or to reduce or mitigate danger to life, health, property, or the environment. (s. 21(2))

Cleanup Orders/Costs

Where a spill has occurred, or might occur, and immediate action is necessary to carry out emergency measures, the inspector may request that these measures be taken by anyone qualified to do so or he may take them himself. (s. 21(3) He may also take whatever measures he considers necessary in order to prevent or reduce any imminent danger to life, health, property or the environment. (s. 9(1) (d)) The recovery of costs of remedial measures is not provided for.

Investigations

The B.C. Act contains no specific provision for investigations following a spill. Inspectors may conduct inspections at any reasonable time for the purposes of ensuring compliance with the Act or regulations. (s. 8(1)) In the course of such an inspection the inspector may examine and remove documents on the grounds that they contain information relevant to the administration and enforcement of the Act and the regulations. (s. 8(2))

Inspectors may be required to produce their certificate of designation prior to an inspection. (s. 7(1))

It is an offence to fail to comply with any reasonable request of an inspector, make false or misleading statements, or obstruct the inspection. (s. 10)

Offences and Penalties

A contravention of the provisions of the Act relating to assisting inspectors or reporting spills and taking remedial measures is an offence. The penalty is a maximum fine of $10,000, or imprisonment for one year or both.(s.16(2))

2.3.3 Environment Management Act, S.B.C. 1981, c. 14
(as am. by S.B.C. 1983, c. 10, 1986, c. 3 and 1989 c. 25)

Jurisdiction

This Act is administered by the Ministry of Environment. It provides for environmental impact assessments where required by the Minister (s. 3), environmental protection orders which allow the Minister to make directions respecting a work, undertaking, or resource use (s. 4), and environmental emergency measures (s. 5). The latter are relevant to spill situations. If a serious spill occurs the Minister may declare an "environmental emergency". (s. 5)

Preventative Measures

This Act contains no specific preventative measures.

Reporting and Required Remedial Measures

This Act contains no reporting requirements or immediate remedial response measures. This Act is primarily concerned with response to the emergency or spill after it is identified.

Clean Up Orders/Costs

Where an environmental emergency has been declared the Minister or any public officer of his ministry "may order any person to provide labour, services, material, equipment or facilities or to allow the use of land for the purpose of preventing, lessoning or controlling the hazard." (s. 5) A public officer issuing the order must have the written authorization of the Minister to do so. (s. 5(2)). Where the Minister has declared an environmental emergency, the Act specifies that the director of PEP (the Provincial Emergency Program) shall not "exercise his powers" under his enabling legislation, the Emergency Program Act.

Where costs are or will be incurred by the Minister pursuant to section 5 they may be immediately paid out of the consolidated revenue fund. (s. 6(1)) Subsequently they are a debt due to the government and are recoverable against "the person whose act or neglect caused or who authorized the events that caused the environmental emergency." (s. 6(3))

Investigations

"The Minister, members of the board, conservation officers and other persons the Minister designates in writing, have for the purposes of the Act the right to enter any property except a private residence." (s. 8)

A search warrant is available to conservation officers designated pursuant to section 9(1). The warrant is available where there is reasonable cause to suspect that an offence under this Act has occurred or is about to occur. (s. 9(3)) Records kept pursuant to other legislation within the jurisdiction of the Ministry of Environment may be seized by the conservation officers. (s. 9(4)) Where production of records is refused a warrant may be obtained from the provincial court. It must be established that "the records are necessary for the administration of the Act." (s. 9(5))

The Minister has broad discretionary powers to hold an inquiry pursuant to the Inquiries Act "whenever he considers it necessary." (s. 7)

Offences

It is an offence to fail to comply with orders made pursuant to an Environmental Protection Order or a Declaration of Environmental Emergency. The penalties are maximum fines of $100,000 for the former and $10,000 for the latter. (s. 14 (1),(2), and (3)) Where a corporation is convicted under this Act, directors or officers of the corporation who authorized, permitted or acquiesced in the offence commit the same offence and are liable to the same penalty for that offence. (s. 14(4)) Where there is contravention of an order made pursuant to an Environmental Protection Order, each day the contravention continues is a separate offence. (s. 14(5))

2.3.4 Pipeline Act, R.S.B.C. 1979, c.328
(as am. by 1980, c.60; 1981, c.16; and 1983, c.10)

The Pipeline Act contains measures for the prevention and containment of spillage.

Every company must make every reasonable efforts to prevent spillage. (s. 38(2)(b))

Where spillage occurs, section 38(2)(c) requires that a company must promptly:

> "(i) "Remedy the cause or source of the spillage,
> (ii) contain and eliminate the spillage;
> (iii) restore and reclaim any land or watercourse effected by the spillage;"

The company must also promptly report to the Minister on the location and severity of the,

> "(i) spillage
> (ii) break, leak or malfunction causing or contributing to the spillage
> (iii) break, leak or malfunction likely to cause or contribute to the spillage",

and action taken or proposed to be taken to prevent or remedy the spillage. (s. 38(2)(d))

Every person who is aware that the spillage is occurring is under a positive duty to report immediately if this has not yet been done. They must also make every reasonable effort to prevent the spillage or assist it in it's prevention. (s.38(3))

Where spillage occurs, or in the Minister's opinion is likely to occur, and appropriate measures to contain and eliminate it are not being carried out, the Minister may order the responsible company or person to do the things he considers necessary to contain and eliminate the spill or he may do what he considers necessary himself. (s. 39(2)) He may also make orders with respect to obtaining the assistance of other companies and persons in the containment and cleanup of the spill or the provision of clean up equipment. (s. 39(2)(c)) Costs of containment and remedial measures may be charged back to any person. (s. 39(4)).

The Minister also has the power to order any company, or group of companies to prepare and implement "a program of measures to contain and eliminate spillage." (s. 39(3))

2.3.5 Health Act, R.S.B.C. 1979, c. 161
(as am by S.B.C. 1981, c. 11, c. 21; 1982, c. 41, c. 43; 1983, c. 10; 1985, c. 7, c. 9, c. 68, and 1987-88, c. 55)

The Health Act provides that in addition to the requirements of the Waste Management Act, a person who causes or permits a spill of a substance that is or may be a health hazard must promptly notify the medical health officer in writing of the location, time, duration, nature and quantity of the spill. The same person is required to take immediate action to prevent and cease the spill. (s. 60(2)

2.3.6 Pesticide Control Regulation, B.C. Reg. 319/81
(as am. by B.C. Reg. 9/82; 48/82; 132/82; 404/83; 47/84; 266/86; 343/87; 203/88; and 230/88) (pursuant to the Pesticide Control Act)

Where a pesticide is involved in a spill that results or may result in its release into the environment, the person responsible for the pesticide shall immediately notify the Pesticide Control Program. (s. 3)

2.4 Federal Legislation

2.4.1 Canadian Environmental Protection Act, S.C. 1988, c. 22
(as am. by S.C. 1989, c. 9)

Jurisdiction and Administrative Authority

This Act regulates toxic and hazardous substances in Canada. It contains spill provisions which are restricted to a "List of Toxic Substances in Schedule I." At present, the list contains only 9 items.

The administrative authority is Environment Canada. The Act is enforced by inspectors appointed by the Minister. Inspectors are not necessarily federal employees. The Act provides that persons employed by provincial administrative authorities may be designated as inspectors under CEPA. (s. 99) At present there are thirty-five inspectors in B.C. and all are federal government employees. Some are with the Environmental Protection Branch of Environment Canada and some are with the Department of Fisheries and Oceans.

Preventative Measures

This Act has no provisions requiring specific measures for the prevention of spills or damage from spills.

Reporting

Section 36 of the Act requires reporting of spills. However, only spills of those substances on the Schedule I - Toxic Substances List must be reported. The wording of Section 36(1) appears to require that the spills must also be in contravention of either a regulation made under section 34 or an order made under section 35. Whether or not this is actually the case is not clear.

There are some regulations and orders as contemplated by section 36. They specify quantities which may be released to the environment but their applicability to spills may be open to interpretation.

Reporting must be "as soon as possible in the circumstances." The provision is applicable not just to spills which have occured, but also to instances where there is a "reasonable liklihood" of a spill occuring. (s. 36(1))

Reporting requirements also include notification of members of the public. It is necessary to "make a reasonable effort to notify any member of the public who may be adversely affected."(s. 36(1)(c)) Conversely, persons whose property is affected by another persons spill are also required to report. (s. 36(3))

Reports are to be made to inspectors (s. 36(1)) or where provinces have adequate spill reporting provisions, and this is declared by regulation under CEPA, the spill report is made to the designated provincial authority. (s. 36(4)) There are as of yet no such regulations. Technically the report must be made to an inspector. However, in practice if the report is made pursuant to the Provincial Environmental Program (PEP), they will contact a CEPA inspector if the spill is within the jurisdiction of CEPA.

Required Remedial Measures

Where a spill of a Schedule I substance occurs in contravention of the regulations it will be necessary to "take all reasonable emergency measures consistent with public safety to prevent the release, or if it cannot be prevented, to remedy any dangerous condition or reduce or mitigate any danger to the environment or to human life or health that results from the release of the substance or may reasonably be expected to result if the substances is released." (s. 36(1)(b))

Where a persons fails to take the required remedial measures an inspector may do so. An inspector, or any other person authorized to take remedial measures, may enter and have access to any place or property to do such reasonable things as may be necessary in the circumstances". (s. 36(7))

Clean Up Orders/Costs

Under s. 36(5) of the Act, where a person fails to take the required remedial measures an inspector may "cause them to be taken" or direct the persons responsible to take them. The federal government may recover the reasonable costs and expenses of and incidental to taking any clean up measures. (s. 39(1) and (2)) Costs are recoverable from either or both the person responsible for the spilled substance or any person who caused or contributed to the spill. (s. 39(1) and s. 36(2))

Investigations

Inspectors have the authority to enter and inspect premises at any reasonable time for the purpose of ensuring compliance with the Act and regulations. The inspector must have grounds for the entry and inspection which are fairly narrowly specified and may or may not apply in the event of a spill depending upon the substance spilled and the nature of the operation relating to the spill. (s. 100(1))
When exercising powers of entry inspectors must carry with them a Certificate of Designation and must be prepared to produce it upon request (s. 99(2))

Inspectors may,

> "(a) examine any substance, product, fuel, cleaning agent or water conditioner referred to in subsection (1) or any other thing relevant to the administration of this Act that is found in the place;

> (b) open and examine any receptacle or package found that the inspector has reason to believe contains any substance, product, air contaminant, fuel, cleaning agent or water conditioner;
> (c) examine any books, records, electronic data or other documents that on reasonable grounds the inspector believes contain any information relevant to the administration of this Act and make copies thereof or take extracts therefrom;
> (d) take samples of any thing relevant to the administration of this Act; and
> (e) conduct any tests or take any measurements" (s. 100(5))

They may also,

> "(a) use or cause to be used any computer system at the place to examine any data contained in or available to the computer system;
> (b) reproduce an record or cause it to be reproduced from the data in the form of a printout or other intelligible output;
> (c) take a printout or other output for examination or copying; and
> (d) use or cause to be used any copying equipment at the place to make copies of the record." (s. 100(6))

The inspector must be permitted,

> "(a) to use or cause to be used any computer system at the place to examine any data contained in or available to the computer system for data from which a record that the inspector is authorized to examine may be produced;
> (b) to obtain a physical copy of the record and to take it; and
> (c) to use or cause to be used any copying equipment at the place to make copies of the record." (s.100(7))

Search warrants authorizing broad search and seizure powers may be issued where there are grounds to believe that the Act or regulations have been contravened or there exists evidence with respect to the commission of any offence under this Act. (s. 101(1))

In the absence of a search warrant seizure is restricted to material which is relevant to or provides evidence of a contravention of the Act and must satisfy the following further grounds,

- the material must be required as evidence or forth the purposes of analysis,

or

- the inspector must believe the seizure is in the public interest

The owner or person in charge of the place under inspection must give the inspector all reasonable assistance and failure to do so is an offence. (s.102 and 111) It is also an offence to obstruct the inspector or to provide false or misleading statements. (s. 103)

The Act contains a "tattletale" provision. Any two adults who believe an offence has been committed under the Act or regulations, may apply to the Minister for an investigation of the alleged offence. (s. 108) The Minister is then under a duty to investigate all matters that he considers necessary for a determination of the facts relating to the alleged offence. (s. 109(1)) He must report to the applicants on his progress and expected actions within 90 days of receipt of the application. (s. 109(2))

Although it is not apparant in the Act, the Enviornment Canada statement "Enforcement and Compliance Policy" envisions a distinction between regular compliance "inspection" (Pg.37) and "investigations" where there are reasonable grounds to believe a violation of the Act has occured or there has been a petition by two persons.(Pg.39) This policy statement indicates that inspections will be conducted by "inspectors" and investigations will be conducted by "investigation specialists". ("Investigation Specialists" are not provided for in the Act) The policy states that where entry is required for an "investigation", a search warrant will be obtained unless there exists an immediate danger to the environment or human life, or the possibility of loss of evidence. (Pg.39)

Offences

Providing false or misleading information during an investigation, or failure to assist an inspector, are both summary conviction offences. The penalty is a maximum fine of $200,000 or 6 months imprisonment, or both. (s. 111)

Section 115 of the Act establishes a Criminal Code offence and may be relevant to spills and in particular in the event that proper remedial actions are not taken when a spill occurs. Section 115 provides that,

> "(1) Every person who, in contravention of this Act,
> (a) intentional or recklessly causes a disaster that results in a loss of the use of the environment, or
> (b) shows a wanton or reckless disregard for the lives or safety of other persons and thereby causes a risk of death or harm to another person
> is guilty of an indictable offence and is liable to a fine or to imprisonment for a term not exceeding five years, or to both.

> (2) Every person who, in contravention of this Act, shows wanton or reckless disregard for the lives or safety of other persons and thereby causes death or bodily harm to another person is subject to prosecution and punishment under section 203 or 204 of the Criminal Code."

All contraventions of the Act or regulations, other than those for which there are specific penalties, are summary conviction offences with a maximum penalty of $200,000 or six months in jail or both. (s. 116) Sections 111 and 115 are the only spill related offences for which there are specific penalties. Where offences are continuing, each day the offence continues may result in a separate conviction. (s. 118) Directors, officers, and agents of corporation which commit an offence may be found guilty of the same offence whether or not the corporation was convicted or even prosecuted. Liability arises where the director, officer, or agent "directed, authorized, assented to, acquiesced in, or participated in the commission of the offence." (s. 122, emphasis added) It is possible that agents could include accountants, lawyers or environmental consultants could be considered agents pursuant to this section.

The Act specifically makes provision for defences. In section 125 the defence of due diligence is acknowledged for all offences under the Act except for "fraud" (s. 114), and "damage to the environment or death or harm to persons" (s. 115). For these offences, the defendant must establish that, in addition to due dilligence, there was no knowledge, of or consent to, the offence. (s. 125(2))

Where a convicted offender has acquired monetary benefits as a result of the commission of the offence the court may impose an additional fine equal to the amount of the benefits (s. 129)

Where a conviction is entered the court has the following further powers pursuant to s. 130 of the Act,

> "*130. Orders of court.*(1)Where an offender has been convicted of an offence under this Act, in addition to any other punishment that may be imposed under this Act, the court may, having regard to the nature of the offence and the circumstances surrounding its commission, make an order having any or all of the following effects:
>
> > (a) prohibiting the offender from doing any act or engaging in any activity that may result in the continuation or repetition of the offence;
> >
> > (b) directing the offender to take such action as the court considers appropriate to remedy or avoid any harm to the environment that results or may result from the act or omission that constituted the offence;

> (c) directing the offender to publish, in the manner prescribed, the facts relating to the conviction;
> (d) directing the offender to notify, at his own cost and in the manner prescribed, any person aggrieved or affected by the offender's conduct of the facts relating to the conviction;
> (e) directing the offender to post such bond or pay such amount of money into court as will ensure compliance with any order made pursuant to this section;
> (f) directing the offender to submit to the Minister, on application by the Minister made within three years after the date of conviction, such information with respect to the activities of the offender as the court considers appropriate and just in the circumstances;
> (g) directing the offender to compensate the Minister, in whole or in part, for the cost of any remedial or preventative action taken by or caused to be taken on behalf of the Minister as a result of the Act or omission that constituted the offence;
> (h) directing the offender to perform community service, subject to such reasonable conditions as may be impose therein;
> (i) directing the offender to pay, in any manner prescribed by regulations under section 120, an amount for the purposes of conducting research into the ecological use and disposal of the substance in respect of which the offence was committed; or
> (j) requiring the offender to comply with such other reasonable conditions as the court considers a appropriate and just in the circumstances for securing the offender's good conduct and for preventing the offender from repeating the same offence or committing other offences."

2.4.2 Transportation of Dangerous Goods Act, S.C. 1980-81-82-83, c. 36 (as am. by S.C. 1980-81-82-83, c. 165; 1984, c. 40 and 1985-86, c. 26

"Transportation of Dangerous Goods Act Regulations" SOR/.85-77 (as am. by SOR/85-314; 85-585; 85-609; 86-526; 87-186; 87-335; 89-39; and 89-294)

Jurisdiction and Administrative Authority

A detailed analysis of the constitutional validity of the legislation within the respective federal and provincial transportation of dangerous goods regulatory regimes is beyond the scope of this paper. Generally the federal government is responsible for the international and interprovincial transportation of dangerous goods by air, sea, rail, and road.

The federal legislation is complex, but this is because it is so thorough and comprehensive. Because the federal legislation is so comprehensive, and to promote conformity in transportation requirements across Canada, where provinces have enacted their own legislation they have for the most part adopted the voluminous federal regulations. It has been seen that this is the case with both B.C. and Alberta.

In the Alberta legislation, the province claims jurisdiction only over transportation by highway within the province. (s. 1, "transportation", "vehicle") In the B.C. legislation the province claims jurisdiction over transportation by highway and by railway. (s. 1 "transportation")

The federal Act applies to virtually all forms of transportation (s. 2, "means of transport") with the following exceptions,

> -transport of oil or gas by pipeline which is governed by the National Energy Board Act, or the Oil and Gas Production and Conservation Act, or by the law of the province. (s. 3(4))
>
> -transport in bulk by ship within the meaning of the Canada Shipping Act (s. 3(5))

The "Transportation of Dangerous Goods Regulations", also contain a long list of further specific exemptions from the Act, a review of which is beyond the scope of this paper.

The Act is under the jurisdiction of Transport Canada, Transport of Dangerous Goods Directorate and is enforced by inspectors designated pursuant to section 13(1).

Because the federal regulations have been adopted by both Alberta and B.C., and are covered under those sections of this paper, further discussion of the spill related provisions of federal regulatory regime will be restricted to instances there is deviation from the legislative provisions already described under the provincial Acts.

Preventative Measures

These are as discussed under the section dealing with the Alberta Transportation of Dangerous Goods Control Act.

Reporting

The federal Act specifies that "where there occurs a discharge, emission or escape of dangerous goods or an emission of ionizing radiation exceeding levels or quantities prescribed pursuant to the Atomic Energy Control Act from any container, packaging, or means of transport, the persons who at the time have the charge, management or control of dangerous goods, shall in the manner and circumstances set out in any regulations applicable thereto, report the discharge, emission or escape to an inspecting or to such person as is prescribed." (s. 17(1)) Sections 9.13 and 9.14 of the federal regulations deal with reporting and have been adopted by both the Alberta and B.C. regulatory regimes.

These reporting provisions have already been discussed under the section of the paper dealing with the Alberta Act and further discussion would be repetitive.

Required Remedial Measures

The provisions dealing with remedial actions are specified in the Act and not the regulations. Therefore, the federal provisions on this matter cannot be adopted by the provinces. Each province has enacted their own provisions in their respective Acts.

The federal Act specifies that every person required to make a report must, as soon as possible in the circumstances, "take all reasonable emergency measures consistent with public safety to repair or remedy any dangerous condition or reduce or mitigate any danger to life, health, property, or the environment that results or may reasonably and probably be expected to result from the discharge, emission or escape." (s. 17(2))

Clean Up Order/Costs

Where a spill has occurred, and immediate action is necessary in order to carry out any reasonable emergency measures, an inspector may request that such measures be taken by any person he considers qualified to do so or he may take them himself. (s. 17(3)) The costs are recoverable jointly and severally from any persons who, through their fault or negligence or that of others for whom they are by law responsible, caused or contributed to the spill. (s. 18(1)) On the subject of fault and negligence this Act has an usual provision. Section 18(2) reverses the normal civil law burden of proof in matters of negligence by providing that for the purposes of establishing fault and negligence in order to recover costs, the "defendant engaging in any activity to which this Act applies is deemed to have been at fault or negligent unless he establishes, on the balance of probabilities, that he and any others for whom he is by law responsible took all reasonable measures to comply with this Act and the regulations." This wording is similar to that of the defence of due diligence to a strict liability offence.

Investigations

The provisions regarding investigations of spills are found in the federal Act and not the regulations and so are not adopted by the provincial Acts. However, they are almost the same as those in the Alberta Act. Inspections for the purpose of ensuring compliance with the Act and regulations may be conducted by the inspector. (s. 14(1)) The powers of search and seizure arise where a spill is occurring, or has occurred, or there in imminent danger that a spill may occur. (s. 15(1)) Where an inspector considers it necessary for the prevention of any serious and imminent danger to life, health, property, or to the environment, he may seize and remove goods, vehicles, or containers. (s. 15(1)(f)) Inspectors also have the power to enter any place or vehicle where dangerous goods are handled for the purpose of ensuring compliance with the Act and regulations. (s.14(1)) An inspector may take samples of dangerous goods or remove documents which he has grounds to believe contain any information relevant to the administration and enforcement of the Act and regulations. (s. 14(2)) All reasonable assistance must be provided to an inspector by the owner or person in charge of premises under inspection. (s. 14(4)) It is an offence to obstruct or hinder the inspection or to make false or misleading statements. (s. 14(5))

The Minister also has the power to hold a federal inquiry under the Inquiries Act where a spill or accident has resulted in death or injury to any persons, danger to the health and safety of the public, or damage or danger to property. (s. 20)

Offences and Penalties

Contraventions of the Act are summary conviction or indictable offences subject to a maximum fine of up to $10,000 for a summary conviction offence, and imprisonment for up to one year for indictable offences (s. 6(2)).

2.4.3 Fisheries Act, R.S.C. 1970, c. F-14

(as am. by R.S.C. 1970 (lst Supp.), c. 17 (2nd Supp.) c. 14; S.C. 1976-77, c. 35; 1978-79, c. 13; 1984, c. 31, c. 40; and 1985-86, c. 26)

Jurisdiction and Administrative Authority

The jurisdiction and validity of this federal legislation is the subject of continuing controversy which has never been satisfactorily settled in court. The Act purports to establish jurisdiction for the protection of fisheries in Canada and is administered by the federal Department of Fisheries and Oceans. The provinces have been delegated administration of the Act with respect to all fish and fish habitat in inland waters with the exception of anadromous fish. Anadronous fish are those which migrate from the sea to spawn and rear in inland waters. In British Columbia the Ministry of Environment, Fish and Wildlife Branch in administers the Act with respect non-anadromous fish.

The Act provides for the appointment of fisheries officers and for the designation of inspectors by a certificate from the Minister (s. 38(1) and (2))

Reporting

Section 38(4) of the Act provides that,

> "Where, out of the normal course of events, there occurs a deposit of a deleterious substance in water frequented by fish or a serious and imminent danger thereof by reason of any condition, and where any damage or danger to fish habitat or fish or the use by man of fish results or may reasonably be expected to result therefrom, any person who at any material time
>
> > (a) owns the deleterious substance or has the charge, management or control thereof, or
> >
> > (b) causes or contributes to the causation of the deposit or danger thereof,
>
> shall, in accordance with any regulations applicable thereto, report such occurrence to an inspector or such other person or authority as is prescribed by the regulations."

No specific reporting regulations have been passed.

Failure to report is an offence pursuant to section 40(3)(c).

Preventative Measures

The Act does not establish any preventative measures relevant to the prevention of spills.

Required Remedial Measures

That Act requires that every person who was required to report pursuant to section 38(4) must, "as soon as possible in the circumstance take all reasonable measures consistent with safety and with the conservation of fish and fish habitat to prevent any occurrence referred to in subsection (4) or to counteract, mitigate or remedy any adverse effects that result or may reasonably be expected to result therefrom." (s. 38(5))

Failure to take the required remedial action is an offence pursuant to section 40(3)(e).

Clean Up Orders/Costs

Where an inspector is satisfied on reasonable grounds that there is a spill which threatens fish or fish habitat and that immediate action is necessary, he may take any reasonable measures or direct that they be taken by any person who had a duty to report. (s. 38(6)) In order to carry out these measures an inspector or other person may enter and have access through any place, premises, vehicle, or vessel. (s. 38(8)) Failure to comply with a direction of an inspector under section 38(6) is also an offence (s. 40(3)(f)).

Costs of remedial measures taken in the event of a deposit of a deleterious substance may be charged back to the person or persons responsible. (s. 42(2))

Inspections

The inspector has access to any place or premises for the purpose of ensuring that reports are made and remedial measures are taken. (s. 38(8))

No person shall obstruct or hinder an inspector in the carrying out of his duties or functions (s. 39(1)) and no person shall knowingly make a false or misleading statement to an inspector.(s. 39(2)) Contravention of these provisions is an offence pursuant to section 40(4)(b).

Prior to exercising right of entry an inspector maybe required to produce the certificate of his designation. (s. 38(2))

Offences

Under the Fisheries Act a spill itself may be an offence. Section 36(3) provides that,

> "no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions where such deleterious substances or any other deleterious substance that results from the deposit of such deleterious substance may enter any such water."

Section 40(5)(a) provides that in the event of a prosecution it is not necessary for the Crown to prove that the Act or omission resulting in the deposit was intentional. Thus the offence includes accidental spills.

The penalty for contravention of section 36(3) is a maximum fine of $50,000 for a first offence and up to $100,000 for each subsequent offence. (s. 40(2)(b)) Where an offence is continuing, each new day constitutes a separate offence. (s. 41(1))

Where a person is convicted of a section 40 offence, the Act gives the court the authority to "order that person to refrain from committing any further such offence" or "to take such action specified in the order as, in the opinion of the court, will or is likely to prevent the commission of any further such offence." (s. 41(2))

"In a prosecution for an offence" under section 40 "it is sufficient proof of the offence to establish that it was committed by an employee or agent of the accused whether or not the employee or agent is identified or has been prosecuted for the offence, unless the accused establishes that the offence was committed without his knowledge or consent and that he exercised all due diligence to prevent its commission." (s. 41(3))

The Act also provides a statutory cause of action which could result in civil liability for damage caused by a spill. Pursuant to section 42(3) licensed commercial fishermen who have experienced loss of income due to damage caused by a spill may make a claim for the amount of the income they have lost. The claim is made against the person who owned the substance or caused the spill. (s. 42(1) and (3)) This is an absolute liability action. Negligence or intent does not have to be established, and there is no defence of due diligence. The only substantive defences available are those specified in section 42(4). It is a defence if the spill was caused by,

> "(a) an act of war, hostilities, civil war, insurrection, or a natural phenomenon of exceptional, inevitable and irresistible character."

or

> "(b) an act or omission with intent to cause damage by a person other than a person for whose wrongful act or omission he is by law responsible."

3.0 ISSUES IN COMPLYING THE REGULATORY REGIME

3.1 GENERAL COMMENTS

The discussion of issues raised in this portion of the paper is meant to answer, or attempt to answer, certain questions which will arise in the heat of initial spill response or in subsequent circumstances. Whether or not the questions can be answered, an awareness of them will lead to better spill preparedness. Examples of the provisions giving rise to the issues have been drawn from the legislation reviewed in Part 2.0 of this paper.

3.2 REPORTING EMERGENCY RESPONSE

3.2.1 What is a "Spill"?

When a spill occurs and reporting may be necessary, the first matter to be established is whether or not the substance spilled is a regulated substance pursuant to an Act or regulation. This analysis generally starts with a definition of the substances regulated and may involve a list as well. The most comprehensive list of substances is contained in the federal "Transportation of Dangerous Goods Regulations", as adopted by both the B.C. and Alberta regimes. However, the provisions of this Act only a apply to spills of these substances which occur during transportation. It may be an issue as to whether a spill during loading for transportation is covered by this regulatory regime.

Some legislation broadly defines the substances covered. The Alberta Hazardous Chemicals Act, deals with hazardous chemicals defined as, "any substance" "that may constitute a danger" to "the environment", "plant or animal life", or "human health". (s. 1)

Although the definition of hazardous chemicals is broad, the jurisdiction of the Act with respect to spills is otherwise limited. The provisions dealing with spills apply only to facilities for the storage, treatment, or disposal of hazardous chemicals.

The B.C. Waste Management Act, refers to a "polluting substance" and defines it as "any substance, whether gaseous, liquid, or solid, that could, in the opinion of the Minister, substantially impair the usefulness of land, water or air, if it were to escape into the air, or were spilled on or were to escape onto any land or into any body of water. (s. 10(1))

The next matter to establish is what quantity constitutes a spill. As a practical matter, where this is not specified, which is the usual case, regulatory agencies advise the reporting of all spills no matter how small. The consequence of being found guilty of failure to report are so severe that it is best to expel all doubt about the matter by reporting. However, in some cases the quantities which constitute spills are specified. This is the case with the transportation of dangerous goods regulatory regime. (Table I pursuant to s. 9.13 of the federal "Transportation of Dangerous Goods Regulations") It is part of driver's required training to be aware of these quantities.

3.2.2 Who is Responsible for Reporting and Initial Emergency Response Measures?

The legislation has different ways of describing the person or persons responsible. The Alberta Hazardous Chemicals Act, which has remedial requirements but no reporting requirements, merely refers to "the person responsible for the hazardous chemical". (s. 7.1(1)) Other legislation is, perhaps unnecessarily, more wordy. The B.C. Waste Management Act, refers to "a person who has possession, charge or control". (s. 10(21))

Under the Canadian Environmental Protection Act, (CEPA), the report must be made by any person who "owns or has charge of a substance immediately before its initial release or its likely initial release into the environment", or who "causes or contributes to the initial release or increases the likelihood of the initial release". (s. 36(2))

In an unusual provision under the CEPA, persons whose property is affected by another persons spill will also be required to report. (s. 36(3))

The transportation of dangerous goods regime specifies in the federal regulations that the report must be made by the "person who has charge management or control of the dangerous goods" (usually the driver of the truck) "at the time he discovers, or is advised of the spill". (s. 9.13 of the federal regulations) In the case of the 1989 Byers Transport spill on Alberta highway 831, the spill, a gradual leak , was not discovered until the truck reached its eventual destination although the leak had commenced many hours earlier. Upon discovery of the leak by the consignor, the driver was sent to backtrack his route to investigate. He reported back to the consignor approximately one hour later when he discovered what he thought was the majority of the spill. The consignor then reported. In these circumstances the consignor and the transport company were charged with failure to report immediately. No charges were laid against the driver or other individual employees. This case has not yet gone to trial.

As with the quantity for reporting, any doubt on behalf of an individual as to whether or not they are the one required to report the spill should be resolved by erring on the side of caution and making the report immediately if others who may be responsible are not doing so.

3.2.3 What is "Immediate" Reporting?

Administrative Agencies have made it clear in the enforcement of immediate reporting provisions across Canada that "immediate" means immediate, or as soon as possible in the circumstances. The latter is in fact the wording in CEPA. (s. 36(1)) An example of proper reporting would be the case where the driver of the truck which had a spill left his vehicle, climbed a fence, ran across a farmers muddy field to the nearest farm house and called the police. A driver or person responsible must pursue whichever means of making the report is the most expedient in the circumstances. The only exception would be if there were some immediate remedial action which should be taken such as quickly digging a berm to prevent the flow of the spill into a waterway.

3.2.4 What are Reasonable Emergency Measures?

This issue may be a bit more legislation specific than previous issues discussed. The wording is varied and in some cases fairly precise.

CEPA requires "all reasonable emergency measures consistent with public safety to prevent the release or, if it cannot be prevented, to remedy any dangerous condition or reduce or mitigate any danger to the environment or to human life or health that results from the release of the substance or may reasonably be expected to result if the substance is released". (s. 36(1)(b))

Under the Alberta Hazardous Chemicals Act, the requirement is to "take all reasonable emergency measures consistent with public safety to repair, remedy, and confine the effects of and remove the hazardous chemical in such a manner as to effect maximum protection to human life, health, and the environment". (s. 7(1))

The B.C. Waste Management Act, does not specify immediate remedial measures to be taken by the person responsible.

In the transportation of dangerous goods regimes, remedial measures are defined in the respective provincial Acts.

The B.C. Act refers to "all reasonable emergency measures, consistent with public safety to repair or remedy a dangerous condition or to reduce or mitigate danger to life, health, or property, or the environment". (s. 21(2))

The Alberta Act has an identical provision. (s. 10(2))

In theory, interpreting these provisions is important because if inadequate measures are taken a prosecution may result, or an administrative clean up order could be made, or measures could be taken by the administrative authorities and charged back to the person responsible.

In practice, however, the scope of the measures which must be taken will be determined in consultation with the administrative agencies who would be supervising the cleanup or who have jurisdiction over the spill involved. Close and ongoing consultation is recommended.

3.2.5 When has One Acquired Knowledge of the Spill?

The wording used in the Alberta Hazardous Chemicals Act, is "immediately upon becoming aware" of the spill. (s. 7.1) In the transportation of dangerous goods regime the wording is "at the time he discovers or is advised of the dangerous occurrence". (s 9.13 of the federal regulations) The wording of the B.C. Waste Management Act, is "immediately after he learns of the escape, spill or introduction". (s. 10(5)) This Act deals with the issue further by establishing a reverse onus. In the event of a prosecution, the accused is presumed to know of the spill and he carries the burden of proving otherwise. (s. 10(6)) CEPA requires reporting as soon as possible in the circumstances by persons who are described in comparative detail in section 36(2), but does not address knowledge at all.

In the Byers Transport case, knowledge of the spill may be an issue. Upon initial discovery of the leak a report was not made. Apparently it was not known by the consignor or driver to what extent a spill had occurred on the highway and the driver was sent back to investigate. A report was made once a portion of the spill was found on the road. The issue in this case is whether knowledge of the spill occurred once the leak was discovered, as the Crown will no doubt allege, or later when the presence of spill on the road had been discovered. In retrospect, and as has been stated before, these charges can be avoided by resolving any doubt in favour of immediate reporting.

3.3. AGENCY INVESTIGATION/SEARCH AND SEIZURE

3.3.1 Obstruction of Justice

Most of the legislation reviewed contains provisions which allow for the subsequent investigation of spills by inspectors or other designated persons. It is usually an offence to alter or remove material to be inspected, make false or misleading statements, or otherwise interfere with or obstruct the investigation.

However, the entry, search, and seizure must be valid under the enabling legislation. The persons conducting the investigation must be properly authorized or designated to do so if the legislation provides that some form of designation or authorization is necessary. Moreover, search and seizure powers are usually not without parameters establishing grounds which restrict their availability to certain circumstances and their scope to certain material or actions. which may be investigated and actions.

3.3.2 Production of Proof of Authorization

In most cases the legislation requires that upon request an inspector must produce written proof of his designation or authorization to conduct the investigation. It is not unreasonable to request that the inspector produce evidence that he is properly authorized prior to allowing entry. It is helpful where legislative provisions specifically provide for this, but caution is advised where they do not. The desire to ensure that the investigation is properly authorized may be in conflict with provisions which establish an offence where entry is refused.

Under section 21(1) of the B.C. Waste Management Act, an "officer may at any reasonable time and on presentation of proof of his identity enter on works or land."

Under the Alberta Hazardous Chemicals Act, there is no such provision, however notice must first be given. The Act provides that the investigation will be conducted by "an employee of the Department authorized by the Minister". (s. 10 (1)) The Department means Alberta Environment. The appointment is made pursuant to section 3(1) which provides that the "Minister may in writing appoint an employee of the government or of a government agency to carry out all or any of the provisions of this Act." Although it is not specifically provided for in the Act, it would not be unreasonable to request proof of this authorization, or production of the section 3(1) appointment. Depending on the circumstances though, failure of the inspector to produce evidence of authorization may not be grounds to refuse entry.

Under the Alberta Transportation of Dangerous Goods Control Act, an inspector is "furnished with a certificate of his designation and" "he shall, on request, produce the certificate." (s. 6 (2))

The B.C. Transport of Dangerous Goods Act, contains almost the same requirement. Section 7 provides that "an inspector shall be furnished with a certificate, in the prescribed form, of his designation showing the purposes, classes of dangerous goods, road vehicles or rail vehicles and the buildings or place for which he has been designated". Upon entering any premises or vehicle, the inspector may be required to produce his certificate.

3.3.3. Grounds for Entry, Search and Seizure

In some legislation, "grounds" must be established before either entry, search or seizure powers arise. If this is the case, the Act will specify the circumstances which will constitute grounds. Entry, search and seizure provisions may not be treated consistently with respect to the requirement of grounds. For example, in some cases grounds may be required for seizure, or for search and seizure, but not for entry.

CEPA specifies fairly narrow grounds for inspection. Firstly, the inspection must be for the purpose of ensuring compliance with the Act and regulations. If this is established, section 100(1) further provides that the inspector must have reasonable grounds to believe that,

> "(a) there can be found in the place a substance to which this Act applies or a product containing such a substance;
> (b) a fuel to which this Act applies is being or has been produced or can be found in the place;
> (c) a cleaning agent or water conditioner, as defined in section 49, is being or has been produced or can be found in the place;
> (d) regulations made under section 54 apply to or in respect of the place;
> (e) the place is a source in respect of which regulations have been made under section 63; or
> (f) any books, records, electronic data or other documents relevant to the administration of this Act can be found in the place."

Under the federal Transportation of Dangerous Goods Act, the grounds for inspection are broad. The purpose of the inspection must be to ensure compliance with the Act. (s. 14(1)) But the powers of seizure are restricted to situations where an inspector has reason to believe that there exists reasonable and probable grounds that a spill is occurring or has occurred, or there exists a serious and imminent danger of a spill or a provision of the Act or regulations has been contravened. (s. 15(1) (a),(b) and (c))

The scope of seizure is restricted to "any dangerous goods, container, packaging or means of transport from which the inspector believes the spill has arisen." (s. 15 (1) (d))

Under the B.C. Environment Management Act, entry onto private land may be gained by specified persons without grounds or notice (s. 8) but search and seizure by a conservation officer requires a warrant. (s. 9) In order to obtain a warrant the conservation officer must have reasonable grounds to believe an offence under the Act has occurred or is about to occur. (s. 9 (3)) Prior to exercising powers of seizure the conservation officer must have reasonable or probable grounds to believe that the material to be removed may provide evidence of the commission of an offence under the Act. (s. 9 (3))

3.3.4 Notice Requirements

Legislation either specifies that notice of a pending search must be given, is silent about notice, or specifies that inspections or investigations may be made without notice.

Under the B.C. Waste Management Act, an officer may enter work or land "at any reasonable time". (s. 21)

The Alberta Hazardous Chemicals Act, requires "reasonable notice", but does not further specify what would amount to reasonable notice. (s. 10)

Both the Alberta and B.C. transportation of dangerous goods regimes specify inspections may be conducted at "any reasonable time". (sections 7 and 8 respectively)

Where reasonable notice is specified there may arise an issue as to what amounts to "reasonable notice". The same is true where an inspection may occur at "any reasonable time". In both cases the circumstances will to some extent dictate the interpretation of these provisions. For example, it may be reasonable to search a facility at 3:00 A.M. if it operates around the clock in shifts whereas the same may not be true of a facility that does not.

3.3.5 Scope of Search

Legislation which authorizes investigations usually limits their scope as well.

Under section 10 (1) of the Alberta Hazardous Chemicals Act, the scope of the investigation is limited to,

> "(a) investigating, inspecting, or carrying out tests necessary or desirable under this Act or the regulations,"or
> "(b) examining and making copies of or taking extracts from records or a person"

Under the Alberta Transportation of Dangerous Goods Control Act the scope of the search includes,

> -opening and inspecting containers (s. 7 (1)),
> -taking samples of substances believed to be dangerous goods (s. 7 (3) and (2)),
> -examining and removing for the purposes of making copies and extracts any books, records, shipping documents or other documents or papers believed to contain any information relevant to the administration or enforcement of the Act and the regulations. (s. 7(3))

The provisions of the B.C. Transport of Dangerous Goods Act, on scope of investigations do not differ from those of the Alberta Act in any significant respect.

Under the investigation provisions of the B.C. Waste Management Act, the scope of the investigation is described in comparative detail. Pursuant to section 21 (2) an inspector may,

> -investigate any process, works or activity producing or capable of producing waste or pollution or used in the storage, handling, treatment, destruction or disposal of waste
> -examine and take away records relating to the causing of the pollution, the production, treatment, storage, handling, transportation and discharge of waste, the characteristics of the waste produced, treated, stored, handled, transported or discharged
> -carry out inspections, measurements, and tests on the land or of any articles, substance or waste on it to ascertain the extent of the pollution or measure the quantity of waste produced, treated, stored, handled, transported or discharged

-and take away samples of the land, articles, substance or waste

3.4 OFFENCES

3.4.1 Director Liability - Knowledge

Of the Acts reviewed in section 2.0 of this paper, the following provide for director liability for offences relating to spills:

-Waste Management Act (B.C.) (s. 34(10))
-Environment Management Act (B.C.) (s. 14(1))
-Canadian Environmental Protection Act (s. 122)

Where directors, officers, or agents may be found guilty of offences committed by the corporations they operate, knowledge of the commission of the offence may become an issue. If directors are to be held liable for decisions and actions resulting in a spill, the question arises as to what level of knowledge of, or participation in, the decisions or actions is contemplated. The exact wording of the legislation is important in this respect.

Under the B.C. Waste Management Act, the level of participation in the decision making process is specified by the words "permitted or acquiesced". Both words imply some knowledge but the scope of the word acquiesced could be broadly or narrowly interpreted. If a board of directors vote in favour of approving a new procedure which carries with it a known risk of accidental spills and one board member who may not have been in favour abstains from voting, has he acquiesced in the event that a spill occurs? In another scenario, suppose the board of directors have voted not to conduct an environmental audit because in the event that it might turn up the requirement of costly upgrading of operations which they can not afford. If a spill occurs as a result of failure to upgrade operations, has that board authorized a decision which acquiesces to a situation resulting in a spill?

At its most limited, the concept of acquiescence requires that there must be knowledge (as with the first example), but under a broader interpretation of the concept there may arise a duty to inform oneself (as with the second example). The court decisions under securities legislation may provide helpful precedents on this issue.

Under the B.C. Environment Management Act, the applicable wording is "authorized, permitted or acquiesced."

Under the CEPA it is specified that liability arises where the director, officer, or agent "directed, authorized, assented to, acquiesced in, or participated in the commission of the offence." Of the three Acts under discussion this one is noteworthy because of it's inclusion of agents within the net of liability. Again, cases prosecuted under securities legislation are instructional in the interpretation of who might be considered to be an agent in any given circumstances. In these cases stock brokers, accountants and lawyers have, under varying circumstances been, held liable. It is conceivable that in environmental matters environmental consultants and consulting engineers might find themselves in circumstances where they are liable.

3.4.2 Charges Against Companies for Offences Committed by Employees

In some legislation there are provisions for the prosecution of charges against a company for offences committed employees, whether or not the employees are also charged with the offence. The question arises as to what defence a company has to such charges. In some cases the legislation specifically provides defences.

Under the Alberta Transportation of Dangerous Goods Control Act, section 22 provides that an accused company may be found guilty for the acts of its employees whether or not they are also charged. However, the Act also establishes a defence where it can be proved that the offence was committed without the knowledge of the accused company and that all reasonable steps where taken to prevent the commission of the offence.

The defence of absence of knowledge raises several other issues relating to the circumstances within which a company may be presumed to have knowledge. It might be necessary to determine whether knowledge of manager would constitute knowledge on the part of the company, or at the other extreme, whether it is required that the entire board of directors have knowledge.

The defence regarding "all reasonable steps" is a due diligence defence and companies should give some thought as to what might be reasonable in their circumstances. Careful selection of employees with definable and defensible selection criteria is a starting point. Training and proper supervision might be other considerations. An environmental audit which includes spot checks on employee's conduct and behavior is yet another consideration.

The B.C. Waste Management Act, contains a provision for charges arising from offences committed by employees. In section 34(11) it is specified that it is sufficient proof of the offence to establish that it was committed by an employee or agent of the accused whether or not the employee or agent is identified or has been prosecuted for the offence, "unless the accused establishes that the offence was committed without his knowledge or consent or that he exercised all due diligence to prevent its commission". (section 34(11)) Although the wording is slightly different the effect is the same as discussed above.

CEPA provides that "it is sufficient proof of the offence to establish that it was committed by an employee or agent of the accused, whether or not the employee or agent is identified or prosecuted for the offence." (s. 124) The defence of due diligence is available for all offences with the exception of "fraud" (section 114) and "damage to the environment and death or harm to persons" (section 115). (section 125) For those offences lack of knowledge or consent must also be established. (section 125(2))

3.4.3 Defence of Due Diligence

The due diligence provisions of the legislation reviewed have been set out in this paper under other headings. Whether the wording is "take all reasonable steps" or "exercise all due diligence". It is submitted that the effect is the same. The concept may only be further defined in the context of any given set of circumstances. Some criteria which might be considered are:

-regular environmental audits and risk assessments
-preparation and implementation of contingency plans
-employee training and supervision
-best available pollution control or other relevant technology
-ongoing agency consultation to keep in touch with new policies, developments, issues and concerns
-strict compliance with legislation and permits
-strict compliance with monitoring, reporting and testing provisions in legislation and permits
-establishment of a corporate environmental policy statement
-industry standards (this criteria should not be relied upon if there is reason to believe that industry standards are inadequate or better technology is available)

This list is by no means exhaustive and provides only a few considerations of matters which a court might consider in determining whether the defence of due diligence has been established.

4.0 REPORTING AND AGENCY RESPONSE

Despite what the various Acts and regulations may say about immediate reporting of spills, each province has set up a coordinated environmental emergency reporting and response system.

In Alberta there is the Provincial Emergency Response Team known as PERT. Their 24 hour toll free phone number is 1-800-222-6514 and is listed in the emergency section of Alberta telephone directories. If the call is placed from the Edmonton area or from outside Alberta the number is 427-6225.

In British Columbia there is The Provincial Emergency Program known as PEP. Their 24 hour toll free phone number is 1-800-663-3456. If the caller is calling from the Victoria area or long distance from outside B.C. the 24 hour number is 387-5956.

All spills may be reported to these numbers in satisfaction of the spill reporting requirements of the various federal and provincial legislation reviewed with the exception of spills subject to the requirements of the transportation of dangerous goods regulatory regimes. Transportation of dangerous goods spills across Canada must be reported to the authorities or numbers specified in Table II of section 9.13 of the federal "Transportation of Dangerous Goods Regulations". In Alberta the spill must be reported immediately to the local police. The same is true in B.C. with the exception that the Victoria PEP number, 387-5956, is also listed as an alternative. In B.C. and Alberta if 911 or the local police are contacted, they will usually contact the PERT or PEP systems.

All calls to the PEP and PERT numbers are tape recorded.

PERT (Alberta)

PERT has 10 team members; 5 in Edmonton and 5 in Calgary. Team members work as investigators with the Pollution Control Division of Alberta Environment and are on call on a rotating basis. They have received special training in spill response matters.

Team members have available to them two emergency response trucks; one in Calgary and one in Edmonton. Each truck contains spill response equipment such as sorbents, booms, protective clothing, monitoring equipment; and a lap top computer with a data base. The regional offices of Red Deer, White Court, and Ft. McMurray, each have a scaled down version of the truck and two more are planned for Lethbridge and either Grand Prairie or Peace River.

The oil and gas industry has OSCAR units (Oil Spill Containment and Recovery Units) which may also be called upon by PERT for assistance with oil spills.

In the event of a large spill for which the required equipment and manpower is beyond the scope of PERT, they might contact the Alberta Special Waste Association, (403) 424-6384. This association Acts as an intermediary between the service industry and client's requiring services. The Association will send a fax or letter to their members describing the services required. Those in receipt of the fax or letter who are interested in the business will respond and will be given the potential client's name and phone number. The association is funded by the fees of its members and is a free service to potential clients.

PERT may also call upon local health units or the RCMP for further assistance in appropriate circumstances.

Alberta Dangerous Occurrence Reports under the Transportation of Dangerous Goods Control Act

In Alberta, reports of spills pursuant to the Transportation of Dangerous Goods Control Act, are made to the local police.

The police will contact the Alberta Public Safety Services (APSS) emergency number in Edmonton, 422-9600. Where the spill threatens the environment and requires remedial measures to prevent or mitigate environmental damage the local police will also report the matter to PERT and if they do not it is likely that APSS will. A person reporting a spill could call APSS directly at 422-9600 if the call is from Edmonton, or at the toll free emergency number, 1-800-272-9600.

The role of APSS in a spill situation is more closely related to the events leading up to the spill and compliance with preventative measures and safety requirements. They utilize a computer data base, the Dangerous Goods Information System II, which monitors and processes information on spills and any other emergency or reportable incident in the Province. APSS does not take an active part in matters concerning containment or remediation of the spill. These matters are handled by PERT.

PEP (B.C.)

PEP Acts as a clearing house for calls regarding all emergencies including for example, earthquakes, storms, and tidal waves. When they receive a call regarding an environmental emergency or spill they refer the calls on as follows:

> -if private or provincial land or inland waters is affected: Ministry of Environment, Waste Management Branch, Special Emergencies, 387-9955 (Victoria), (or via a 24 hour dedicated cellular phone number which is not public)
> -if marine waters or federal land (federal parks or indian lands) is affected: Environment Canada, 666-6100 (Vancouver) who in turn may contact Indian and Northern Affairs Canada, Parks Canada, or the Canadian Coast Guard

A call received by the head of Special Emergencies at the Waste Management Branch is referred on to the relevant regional Environmental Safety and Protection Officer (ESPO). Each of the 10 Ministry of Environment regions has at least one officer and two regions have two officers. The officers have at their disposal one truck in each region. The trucks are equipped for response to spills of a minor nature. They contain sorbents, booms, shovels, protective clothing and other emergency response equipment. Each ESPO has received training in accordance with a Ministry of Environment system of levels. The highest level qualifies the ESPO to respond to unknown chemicals with unknown hazards. In responding to such a situation the ESPO wears completely self contained clothing and breathing equipment and must be backed up by another ESPO or person with the same level of training. If another ESPO is not available the local fire department. may be called upon to provide someone with the required training.

To achieve, the necessary training ESOPs are sent by the Ministry of Environment to programs in Houston, Texas or in Peublo, Colorado. The latter program is run by the American Association of Railways.
In addition to the ensuring that ESPO's are properly trained the Ministry of Environment has developed an Emergency Response Manual which acts as a procedural guide and source book. The manual contains as list of suppliers of materials and equipment which might be purchased or rented in the event of a major spill. In some situations the Ministry of Environment may find it necessary to contract out the entire clean up of the spill to private companies.

The Waste Management Branch may enlist the help of other agency personnel such as Wildlife officers from the Fish and Wildlife Branch of the Ministry of Environment, or radiation or other experts from the Ministry of Health, or pesticides experts from the Ministry of Agriculture and Fisheries.

The governments of B.C. and Canada have a memorandum of understanding (MOU) with Environment Canada concerning the division of responsibilities for spills. This agreement is titled, *UNDERSTANDING BETWEEN CANADA AND BRITISH COLUMBIA CONCERNING FEDERAL/PROVINCIAL RESPONSIBILITIES IN OIL AND HAZARDOUS MATERIAL SPILLS*, signed June 26, 1981. Despite the MOU, it is frequently the case that since the federal government does not have as extensive regional capabilities as the provincial government, the Waste Management Branch may end up responding on behalf of the federal government. Occasionally the reverse is true and the federal government will respond on behalf of the Waste Management Branch.

5.0 CONCLUSIONS

This paper has reviewed the Alberta, B.C. and federal legislation applicable to spills. Issues encountered in complying with the legislation have been discussed. The agency spill response regime in B.C. and Alberta has been described. The objective has been to become informed of the conduct necessary for regulatory compliance in situations of spills or potential spills.

It has been seen that, with a few exceptions, in most cases there is regulatory compliance if there is due diligence. However, it has also been seen that due diligence as a defence is fairly difficult to define except in the context of a specific set of circumstances. This being the case, it may be more helpful to think of due diligence as an attitude which shapes everyday conduct and short or long range planning.
If this attitude is present in the environmental or business policy of a company and a major spill occurs, the chances of liability for regulatory offences is greatly reduced.

In the ideal situation, when a spill occurs, the company responsible has conducted a recent audit and risk assessment as part of a regular audit program. We may presume the audit identified and quantified the risk of the spill. A comprehensive contingency plan was prepared and the availability of emergency funding, equipment, and personnel for a clean up established.

The company has implemented the contingency plan in a timely manner and has thereby complied with requirements for immediate remedial measures. Reporting occurred immediately because staff was trained to do so and all the relevant phone numbers and contacts were at their fingertips in the contingency plan.

All other legislative requirements have been complied with, having been identified in advance by audit and incorporated into the contingency plan.

An full scale agency investigation is about to occur but the executive and staff are ready. They will assist the inspector in any way possible within the scope of the investigation. The potential scope of, and grounds for, the upcoming investigation are understood as they also were identified in the audit and are described in the contingency plan.

The companies lawyers will be pleased with conduct of the investigation. Their client will provide them with copies or duplicates of all evidence and samples collected by the regulatory authority during the investigation. In the event of a prosecution, the lawyers will not be in the difficult position of having no knowledge of the evidence gathered against their client. This has occurred because the lawyers were involved in the audit and their advice on dealing with investigations was incorporated into the companies contingency plan.

Spill clean up is continuing and will continue for several months in accordance with the contingency plan. An important part of the clean up process is ongoing monitoring of the progress.

Meanwhile a vigorous internal corporate investigation is occurring. Some quesions being addressed are:

-how did this spill occur?
-was the risk of this spill properly identified in the last audit?
-is another audit necessary?
-were measures taken in response to the audit to reduce the risk of the spill as much as possible using latest available technology
-was the contingency plan adequate or should it be reviewed and revised?
-was the contingency plan properly implemented?
-did employees respond appropriately?
-was employee training and supervision adequate?
-at what executive level does responsibility for the spill rest? Is the corporate decision making structure at fault?

This internal investigation should result in an aggressive action plan which identifies measures to be taken to reduce the likelihood of another spill and to be better prepared to mitigate the damages of another spill if it does occur.

These internal investigations are now legislative requirements in some U.S. jurisdictions.

Throughout the initial spill response and subsequent remediation and investigation period the companies relationship with government agencies and the public has been characterized by, forthrightness communications policies.

Forthright communications with agencies, other parties affected, and the public, is an extremely important and often underestimated element in the conduct of a company in responding to a major spill. The conscientious company in the above scenario is aware of this because it was also identified in the last audit. The audit pointed out that there is no denying the general public's present concern over environmental matters. As of the past two years the public have rated environmental matters as the most important issue of the day. This attitude shapes the legislative activities of governments, affects the enforcement practices of administrative agencies, and influences the approach to decision making by the courts. Given this situation it should be apparent that nothing more than absolutely forthright communications will be tolerated by the public, agencies, and courts in assessing the conduct of a company. Companies may be reminded that where a major spill occurs, cases are usually tried in the media before they get to court.

With these considerations in mind, the company in the above scenario reported and announced the spill immediately. Moreover, they have been making constant reports and announcements on the progress or latest developments during the clean up and remediation periods. They are also keeping the government agencies and public abreast of progress made on their internal investigations and plans for the prevention of another similar spill.

The above is a scenario of due diligence in spill response and spill preparedness.

CHEMICAL SPILLS IN ALBERTA - A 1989 PERSPECTIVE

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ABSTRACT

The Transportation of Dangerous Goods legislation came into force in the Province of Alberta in the the mid-1980's. Up to that time, the reporting of chemical spills to a provincial government agency was limited in scope. The reporting requirements of the legislation increased the incidence of reported occurrences, with the frequency of road transport highway spill reports remaining relatively constant during the period 1986 through 1988.

In the early part of 1989, several high profile spills on Alberta highways resulted in a significant increase in public awareness in relation to the transport of dangerous goods on the highways of Alberta. This increased awareness led to a much higher frequency of spill reports to the provincial government. A review of the trends of spill reporting prior to 1985/86 is presented and a viewpoint on th e impact of public perception on the reporting frequency during 1989 is given. Case studies from the year are also presented.

Introduction

Alberta Public Safety Services is a provincial governent Agency charged with coordinating government response and assistance in the event of disasters and emergencies which threaten the general public of the province. In 1982, this responsibility was extended to include the provincial dangerous goods control program. In this role, the agency is in a unique position to gather data on dangerous goods incidents occurring in the province.

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The federal Transportation of Dangerous Goods Regulations came into force July 1, 1985. This legislation specifies that certain kinds of incidents involving dangerous goods must be reported to the local police and that "Dangerous Occurrence" reports must be filed with Transport Canada. The Province of Alberta adopted the federal regulations began enforcing them February 1, 1986. The provincial program is supported by the Dangerous Goods Control Division of APSS. The initial emphasis was on voluntary compliance. The regulations were new and complex, especially for small companies and industries and an extensive "Compliance Information" program was conducted. Through an extensive awareness program, shippers, carriers and receivers of dangerous goods were made aware of the reporting requirements of the new legislation. Through arrangements with local police departments, including the RCMP, and other provincial and local government departments, the Coordination and Information Centre (CIC) of APSS receives notification of dangerous goods incidents occurring in the process. Industry awareness is high and a number of reports are made by individual companies direct to the CIC. In addition, any incident which require Dangerous Occurrence Reports are reported by Transport Canada.

APSS has gathered data on dangerous goods transportation incidents over the last four years since the introduction of the Provincial legisalation. The primary duty of APSS in any incident is to facilitate the response to the incident by providing any information required, locating resources, and providing additional communication facilities. In fulfilling this role, the CIC is able to collect data on the numbers, types and effects of incidents. While not exhaustive, this data provides an effective description on the characteristics and trends of dangerous goods incidents in Alberta.

Prior to the implementation of the dangerous goods program in the province, a study[1] was undertaken by Stanley Associates Engineering Ltd. (SAEL) which determined the volumes and traffic flow patterns for these commodities in Alberta. This report was published in 1984 and represents a base case "snapshot" of the movement of dangerous goods in Alberta. This study did not include dangerous goods shipped in so called "Less than Load", (LTL), quantities or mixed load shipments. In addition, the study did not include the volumes of diesel and molten sulphur transported in the province since at that time, Transport Canada did not intend to regulate these products. These products are included in the Regulations as of August 1, 1989.

The period 1984-90 includes a number of major events. Not only did the Transportation of Dangerous Goods Regulations become law but also the

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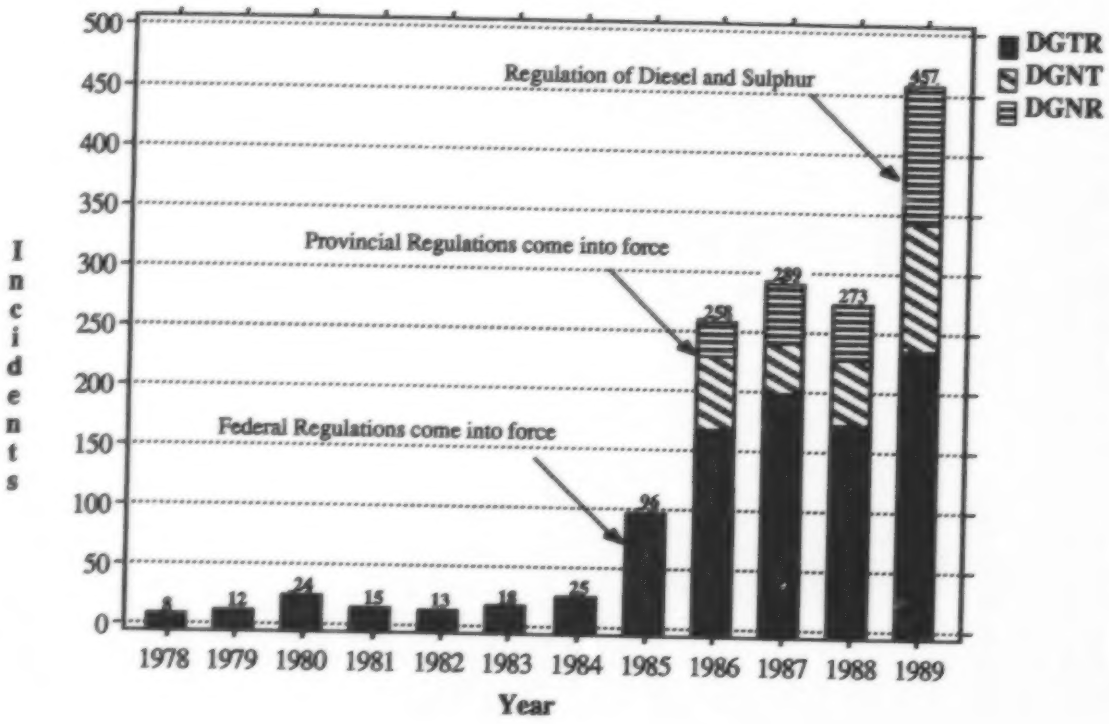
[1] Transportation of Dangerous Goods in Alberta, Stanley Associates Engineering Ltd, August 1984 for Alberta Economic Development and Trade

Figure 1:

Incidents Reported to APSS
1978 - 89



WHMIS Occupational Health legislation extended chemical awareness to the work site. In addition, over this period, there has been a growing awareness and concern on the part of the general public on the effects and impact of hazardous commodities on people and the environment..

Reporting Frequencies

Figure 1 displays the number of incidents reported to Alberta Public Safety Services over the period 1978-89. From an initial 8 incidents in 1978, several years before the dangerous goods control program was begun, to a high of 458 incidents in 1989, there is a dramatic increase in the number of incidents reported. The major increases in incident reporting coincide with the coming into force of the regulatory requirements on mandatory reporting. A second major increase occurs when diesel and molten sulphur become regulated products. A third increase is observed to have occurred just after high profile incidents in 1989.

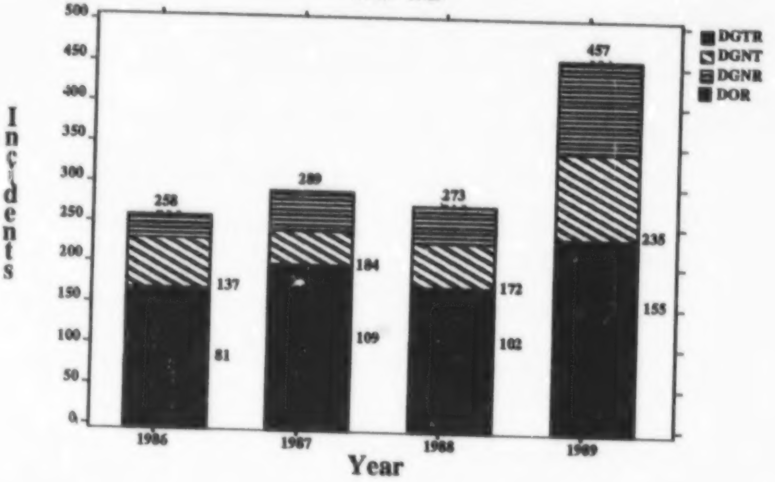
After 1985, the incidents are subdivided according to whether the product was regulated and in the transportation mode at the time of the incident (DGTR), or whether the product was regulated but not in the transportation mode at the time of the incident (DGNT), or whether the product involved was not regulated at all, (DGNR).

DGTR totals include any incident which involved a regulated product in the transportation mode. These therefore include incidents involving small, perhaps inconsequential spills. The incidents may or may not require a mandatory report to the local police or a Dangerous Occurrence Report (DOR) to Transport Canada.

DGNT totals include any incident involving a regulated product which did not come under the jurisdiction to of the Transportation of Dangerous Goods Regulations at the time of the incident. The regulations cover the handling, offering for transport and transporting of dangerous goods. This interpreted to mean that the regulations apply from the loading dock of the shipper to the loading dock of the receiver and include loading and unloading operations. Any spills of a regulated product such as gasoline which occurred from a site storage tank would be recorded as a DGNT incident.

DGNR incidents include any incident involving a product or substance which is not regulated by the regulations. For example, diesel was not a regulated product for road mode transportation until August of 1989. At that time, it became regulated. Diesel incidents are therefore DGNR before August 1989 and DGTR after that date. This classification category will always include any incident to a dangerous goods type response was made

Figure 2:



All Incidents Reported to APSS
1986 - 1989

even although it subsequently was determined that the product was innocuous. This includes many incidents involving non-hazardous spills on highways.

Reporting frequencies will be affected by whether or not the product is regulated. The mandatory reporting requirements are not onerous and are a simple codification of what had been standard practice. In consequence, it is estimated that reports of spills falling within the mandatory reporting levels are close to 100%. Supporting evidence for this is shown in figure 2. This shows the relative numbers of incidents requiring reports. In 1986, 49% of DGTR incidents required a Dangerous Occurrence Report. From 1987 to 1989, this percentage increased to 55%, 59% and 67% respectively. In 1989, two thirds of reported DGTR incidents required a DOR. This indicates two main points.

There is a large amount of "over" reporting of incidents. Incidents are reported which are not covered by the regulatory requirements. As industry becomes more expert in diagnosing the impact of incidents and develops a consistent interpretation of the regulations, the relative frequency of reporting increases. This large over-reporting of incidents is increased when the DGNR and DGNT incidents are included. This is positive evidence that reporting frequency is high in Alberta.

A comparison of reported incidents with Dangerous Occurrence Reports showed that there were only three road mode incidents which first came to the attention of APSS through a DOR. This suggests that APSS is receiving close to 100% notification of all major dangerous goods incidents.

It is expected that there are some incidents which are neither reported to either to the police or any other government agency. In Alberta, this is possible because there are large portinos of the province which are isolated. Recovery is difficult and response slow. These incidents will usually represent a hazard to the environment rather than an immediate hazard to the general public.

Table1: Road Transportation of Dangerous Goods in Alberta

DANGEROUS GOODS CLASSIFICATION	TRUCKLOADS	%	TONNES	%
1 Explosives	3,611	1.2	24,804	1.2
2 Compressed Gases	61,145	20.7	1,142,210	20.7
3 Flammable Liquids	211,712	71.6	5,583,612	71.6
4 Flammable Solids	994	0.3	34,350	0.3
5 Oxidizers, Organic Peroxides	9,795	3.3	206,948	3.3
6 Poisonous or Infectious	1,164	0.4	19,799	0.4
7 Radioactives	0	0.0	0	0.0
8 Corrosives	6,143	2.1	164,772	2.1
9 Miscellaneous	1,019	0.3	21,647	0.3
TOTAL	295,583	100.0	7,198,142	100.0

ref: Transportation of Dangerous Goods In Alberta, SAEL, 1984

Incident Frequency

In 1984, the total quantity of dangerous goods moving in Alberta was approximately 13 million tonnes. This figure excludes diesel, molten sulphur, LTL and mixed load shipments. Of this total, 7.2 million tonnes were carrier on highways in approximately 300,000 truck loads. Table 1 summarises the results of the Stanley and Associates report.

From the SAEL report, it is estimated that there are 1.06 billion tonnne kilometres of dangerous goods on Alberta Highways. This represents 7.2 million tonnes being carried in 296,000 truckloads. The average truck load is 24.3 tonnes and the average trip is 250 km long.

The probability of a spill occurring is found by:

P=(Number of incidents / truckloads) x (length of route)

Figure 3 displays the number of road mode incidents which occurred while under the control of the Transportation of Dangerous Goods legislation. The incidents have been separated according to whether a large tank or bulk unit was involved (larger than 454 litres) or a small packaging. The SAEL report only includes the former.

For 1988, the probability of a spill can be estimated by:

$$P_{spill} = (250 \times 73 / 330{,}000) \times 250$$

$$P_{spill} = 0.0002 \text{ Incidents/Load}$$

similarly,

$$Pt_{spill} = (73/1{,}160{,}000{,}000) = 6.28 \times 10^{-8} \text{ Incidents/tonne km}$$

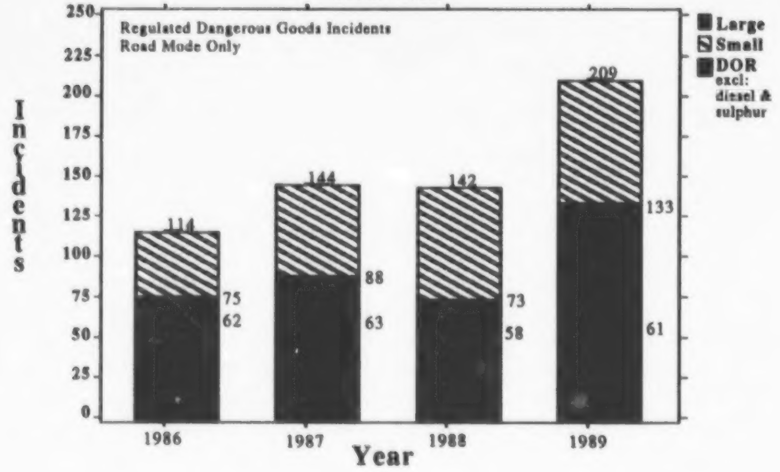
This estimates that an incident involving truck load quantities of dangerous goods will occur every 4,520 trips. This does not evaluate the risk of a dangerous goods incident, only the liklihood that one will occur. Risk is a function not only of the probability of an event but also the probable effects or consequences of that event. For example:

$$R_{spill} = \text{Spill Probability} \times \text{Spill Consequences}$$

The effects of spills may be quantified in several key areas, cleanup costs, restoration costs, health effects, insurance claims for example. This extensive data is not available for all the dangerous goods incidents in Alberta during th e period 1986 - 89. However, the Transportation of Dangerous Goods regulation Dangerous Occurence Report does provide a mechanism for identifying the more serious incidents overt that period.

An incident that requires a DOR is one in which the product involved has either been released in sufficient quantities so as to present a serious hazard or

Figure 3:



Container Size

1986 - 1989

there has been damage to a container which threatens an even greater release. The requirement for a DOR may therefore be used as a measure of the potential consequences. The DOR sections of figure 3 shows the number of large container incidents, road mode incidents which required filing of a Dangerous Occurrence Report. The number for 1989 has been adjusted to exclude the 33 diesel and sulphur incidents which occurred from August 1st onward.

It is clear that although the number of incidents reported has increased substantially over the period 1978 - 89 and particularly in the period 1988 - 89, the number of large container incidents has remained at the 60 incidents per year level. If it is assumed that the number of truckloads on the highways increases each year, these figures suggest that there is a slight trend to fewer incidents involving large vehicles. A second survey is being conducted to analyse the current truck demographics in Alberta.

The probability of a spill, involving a large container, serious enough to require a DOR is:

$$P_{DOR} = (61/330{,}000) = 0.00018 \text{ Incidents/load}$$

This indicates that a major spill, damage to a tank, fire cr explosion involving large truckloads, on average about 24 tonnes may be expected to occur once in every 5,409 trips.

Case Studies

A large number of spills were reported to APSS during 1989. The Highway 831 spill ignited public interest in the issue and resulted in a excess of reports outside of the reporting requirements of the Transportation of Dangerous Goods Control Act. Many of the incidents that have occurred in Alberta in the past 3 years have resulted in legal action, many under the dangerous goods legislation, others being civil lawsuits in relation to the incident and response or cleanup. The case studies shown below are summaries of the incidents, with one objective in mind - to show that spills and spill cleanup cannot be correlated by way of their chemical hazard and the length or complexity of response and cleanup. Each spill has to be evaluated on its own and appropriate response and cleanup objectives set to meet the criteria for public safety.

Case 1

SODIUM DICHROMATE SPILL, Highway 831, Lamont, 31 March, 1989
The spill that set the tone for the increased number of reports during 1989 occurred early on Friday March 31, 1989. A freight unit hauling goods to Fort McMurray left Edmonton at approximately 11:00pm on Thursday, March 30, using Highway 15 through Fort Saskatchewan, Highway 637 at Lamont and turning north on Highway 831. Approximately 1 mile before the turn, a 250 gallon Rigid Intermediate Bulk Container (a "poly tote tank") containing a class 9 dangerous good, sodium dichriomate in solution, failed. The failure was not catastrophic, rather a semicircular split around a recessed valve in the base of the tank, resulting in a steady leak from the tank into the freight trailer. The leak was not discovered until the unit reached its destination. The resulting spill covered an extremely long stretch of Highway 831 from the 637 intersection to the Waskatenau bridge across the North Saskatchewan river, with isolated spills from that point to the 831/63 junction in Boyle, and localized spills at House River Hill, Marianna Lake and at the Fort McMurray destination. The liquid solution dried and by the time a response was activated and the full extent of the spill evaluated the solution had dried completely. A very long and difficult cleanup resulted, with sections of Highway 831 closed for a period up to 14 days. As a result of the spill, the federal and provincial governments issued a stop order prohibiting the use of the RIBC manufactured by a particular manufacturer in dangerous goods service.

Case 2

NON-REGULATED LIQUID POLYMER SPILL, Yellowhead Trail - 11 August 1989. Twenty pails of a non-regulated liquid polymer fell from a flatbed truck, after the shrink-wrap packaging failed. Seven pails split, resulting in a spill of about 200 litres of product. While this product is not considered hazardous, the spill resulted in very dangerous driving conditions on the Highway. The hazard to the travelling public was such that extensive cleanup was required, including some resurfacing of the ramp leading to the Yellowhead Trail. The mile long section of roadway was closed overnight while the work was completed. In this case the emergency response phase was short and relatively low key, but the cleanup process was lengthy and involved.

Case 3

GASOLINE SPILL - Highway 63, Atmore - 16 August, 1989 A B-Train containing both leaded and unleaded gasloine left the road 10 miles north of Atmore, Alberta, rolled and spilled 48 000 litres of gasoline. Highway 63 is particluarly vulnerable to spills due to the volume of dangerous goods transported and the absence of alternative routing to Fort McMurray. The majority of the spill ended up in a dry creek bed, and temporary detours ariound the site were established using secondary roads in the area. The carrier response team arrived inside 3 hours to support the local emergency response, the unit was emptied and much of the spill was vacuumed up. The temporary detour around the accident scene was used until the atmosphere on the highway at the scene fell below the lower explosion limit. Approximately 30 000 litres were recovered from the spill with rest being cleanud up during the restoration process. The incident response proceeded smoothly with assistance from the carrier and local industry. Highway 63 was closed for approximately 10 hours.

Figures 4 and 5 show the effect of these spills on reporting frequencies. The Highway 831 spill (case 1) resulted in an immediate increase in the number of incidents reported to APSS. This effect is matched by a similar increase in the number of information enquiries received in that period. A smaller but effectived increase occurred during the August period of 1989 corresponding to the high profile incidents occurring in that month. Incidents reporting remained high for the remainder of the year. Consequently, although the actual potential threat of these incidents was low, these incidents had a major effect on public and industry's perception of dangerous goods spills. This was sufficient to increase reporting of spills by 80%. In fact, the number of serious spills and incidents actually remained unchanged.

Figure 4:

All Dangerous Goods Related Incidents Report to APSS
1986 - 1989

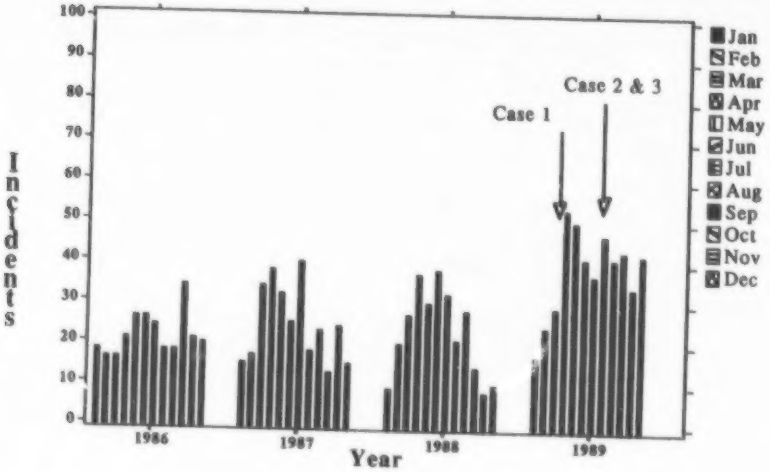
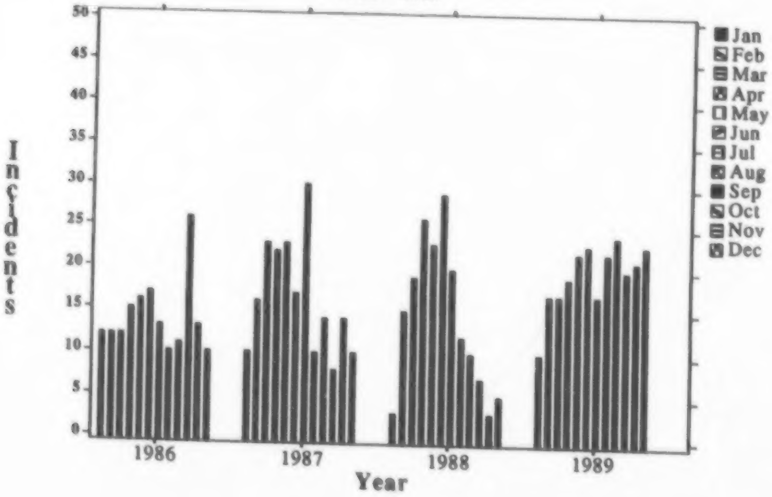


Figure 5:

DG Transportation only
1986 - 1989



Conclusions

Incident statistics for the period 1986 - 89 suggest that there is a slight downward trend in incidents involving large truckloads of dangerous goods. This period corresponds to the introduction and enforcement of the Transportation of Dangerous Goods Legislation in Alberta. This program combines an information and enforcement approach to achieving compliance. It is suggested therefore that the legislation has achieved its desired effect of improving safety. Until more accurate estimates of trucking activity are obtained, this improvement cannot be quantified.

The effect of publicity on reporting rates is very significant. The effect is localised to the area of publicity. The Highway 831 incident increased reporting in the Edmonton area, not the rest of the province.

Although the potential consequences of an incident can be quantified and an estimate of risk made, this calculation does not reflect the real costs of an incident. These costs are a unknown function of public perceptions of the risk in addition to the quantifiable effects of the spill itself.